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U. S. FOREST SERVICE
50 SEVENTH STREET, N. E.
ATLANTA 5, GEORGIA

February 28, 1951

REPORT OF THE
FIRST SOUTHERN CONFERENCE ON FOREST TREE IMPROVEMENT

HELD IN ATLANTA, GEORGIA JANUARY 9-10, 1951

(UNDER THE AUSPICES OF THE U. S. FOREST SERVICE)

ADVISORY COMMITTEE ON FOREST TREE IMPROVEMENT

(Appointed as instructed by the Atlanta meeting by co-Chairmen Haig and Connaughton)

Carl Ostrom - Chairman
Southeastern Forest Experiment Station, Asheville, N. C.

D. A. Anderson, Texas Forest Service, College Station, Texas

E. B. Price, South Carolina Forest Service, Columbia, S. C.

G. I. Garin, Alabama Polytechnic Institute, Auburn, Ala.

C. M. Kaufman, School of Forestry, N. C. State, Raleigh, N. C.

T. E. Bercaw, Gaylord Container Corp., Bogalusa, La.

P. T. Lannan, West Virginia Pulp and Paper Co., Georgetown, S. C.

Keith Dorman, Southeastern Forest Experiment Station, Asheville, N. C.

P. C. Wakeley, Southern Forest Experiment Station, New Orleans, La.

Floyd Cossitt, U. S. Forest Service, Atlanta, Ga.

George Hepting, Bureau of Plant Industry, Soils, and Agricultural Engineering, Asheville, N. C.

E. G. Wieseheugel, Tennessee Valley Authority, Norris, Tenn.

Duties: To advise various agencies on coordination of forest tree improvement research and disseminate information on this subject. The reports of the Atlanta meeting committees will serve as a guide to this Committee, although those reports are neither mandatory nor restrictive.

COMMITTEE ON GEOGRAPHIC RACES

We recommend:

1. A regionwide cooperative study of geographic races of loblolly, slash, longleaf, and shortleaf pines.

2. A representative standing comittee be appointed for the purpose of planning the study and interpreting results.

3. Because of the present enormous size of the planting program in the South, the cooperative study should be designed to give useable results at the earliest possible date.

Pending useable results from the proposed regional study, the committee wishes to emphasize:

a. Any plantations made at a considerable distance or under markedly different climatic conditions from the seed source must be regarded as either experimental or highly risky projects.

b. The geographic source of seed should be an integral part of each plantation record. This will entail seed collectors and nurserymen recording seed source data at time seed is obtained and maintaining such record during seedling production and distribution stages.

W. H. Fischer, Chairman
C. F. Korstian
A. C. Shaw
P. C. Wakeley

CONFERENCE ON FOREST GENETICS RESEARCH IN SOUTHERN PINE

Report of Committee on Hybridization

The objective of hybridization is to obtain increased productivity with improved quality to meet utilization requirements.

To meet this objective and to facilitate the work necessary to attain it, the following three-point program is recommended:

A. Exploratory studies to develop information and techniques

1. Investigation of mode of inheritance of various characters, particularly dominance and recessiveness of specific characters.
2. Development of methods for obtaining combinations of characters desirable in a hybrid.
3. Cytological studies in number and behavior of chromosomes in hybrids.
4. Development of methods for inducing amphidiploidy in interspecific hybrids.
5. Explore the genus Pinus for possible breeding material which might be used in breeding work with the southern pines.
6. Development of techniques for stimulating and controlling time of flowering and methods of artificial dwarfing of mother trees to increase ease of carrying out breeding work and seed collection.
7. Studies of the correlation between juvenile and adult characters as a basis for seedling selection.
8. Development of techniques for testing hybrids.
9. Development of equipment for facilitating hybridization work, such as climbing equipment.
10. Development of techniques for control of mass pollination. (Hot water technique for killing pollen.)

B. Breeding studies using intra- and interspecific crossing to obtain specific objectives

1. Increased volume yields.
2. Pest resistance.

3. Good stem form.

4. Adaptability over a satisfactory range.

5. Slender branching.

6. Satisfactory relationship between spring and summer wood.

7. Heat and frost hardiness.

Cooperative regional testing of hybrids is necessary for adequate accomplishment of tree breeding work.

C. The committee also recommends that:

1. Adequate machinery be set up for the exchange of information and material between workers.

2. A standard system of record keeping be established.

3. Cooperative regional testing of hybrids.

A. D. Folweiler, Chairman
Keith Dorman
C. M. Kaufman
Scott Pauley
H. S. Perry

COMMITTEE REPORT - THE PRODUCTION OF SUPERIOR SEED

Recognition of the need to consider the quality of the seed in all regenerations is gaining momentum throughout the South. The limited information on geogrpahic sources now available should be placed in the hands of all. The wide gaps in these data are apparent to the committee and until such are supplied, it is urged that local seed of known origin be used in so far as possible. In all instances, seed source will be made a matter of record.

As a part of the program for superior seed, the following is recommended for immediate consideration:

1. All seed sown in the nurseries will be of known origin. Seed dealers should be requested to certify all seed as to species, purity, and origin. The latter will designate the State and County or group of Counties from which the seed is collected.

2. Seed source will be furnished all planters at the time of establishment. Continued and increasing emphasis should be placed on the selection of the proper species for the site to be planted.

3. In so far as possible, seed will be selected from trees native to the locality, of good form and rate of growth.

4. Organizations responsible for seed production or procurement are urged to establish seed production areas. These will be so managed whereby the best possible seed in the greatest quantity be obtained over a period of years. The effect of such designated areas is to serve as a source of seed over a period of years until seed is available from trees of proven superiority.

5. All in need of seed should be prepared to take advantage of bumper seed crops and secure seed in sufficient quantities to meet anticipated needs. It is urged that collections be limited to trees of better form and growth rates.

In order to implement the several points in the preceding section, the following lines of investigation are suggested:

1. A tabulation from which acreage and estimated seed yields can be estimated in connection with seed-producing areas.

2. A definition of an acceptable tree suitable for seed production.

3. The optimum number of trees to be left in a seed production area.

4. Coordinating with the geographic. Same committee determines the number and approximate locations of seed procuring areas for a given area.

5. Initiation of experiments pointing toward the stimulation of seed production. This would include the use of fertilizer of various kinds, also include banding, wounding, and other techniques.

6. Initiate a canvass of the larger landowners, both public and private, to ascertain the extent each is willing to cooperate in the establishment of seed-producing areas.

The development of a seed orchard composed of plus or elite trees or their progeny is being left to the committee on phenotypes.

F. M. Cossitt, Chairman
Michel Afanasiev
R. T. Clapp
W. K. Beichler
P. T. Lannan
P. R. Wheeler

NATURAL VARIATION AND SELECTION OF SUPERIOR PHENOTYPES

I. Program Recommendations:

1. That a guide to the selection of superior southern pines be obtained from the Southeastern Forest Experiment Station, reproduced, and distributed by the Central Genetics Committee to interested agencies, groups or associations. Suggestions for improvement or modification should be requested.

2. The Central Committee should request cooperating agencies to actively engage in the selection of superior trees and make necessary progeny tests in accordance with procedures to be developed.

3. A Committee on progeny testing be appointed to collect and distribute information on acceptable procedures for progeny tests. This should be distributed in preliminary form to all cooperating agencies for comment so that the largest area of agreement may be achieved with respect to the principles involved.

4. The need for cataloging elite and other selected strains of southern pines should be recognized. Information on existing selected strains should be collected and made available to the cooperators for their information and use in cataloged form by the Central Committee.

5. Cooperating agencies should be encouraged and requested to conduct studies on the reproduction of southern pines, both by grafting and cuttings to determine the cheapest method for vegetation propagation.

6. Arrangements should be made for the selection and development of arboretums, geographically and climatically distributed, to be used for the further propagation, testing, and holding of phenotypes selected by the cooperating agencies. It is thought that agencies such as the Forest Service, Forestry schools, TVA, and certain private agencies should assist in this project. At least four areas should be selected, one of which should be west of Mississippi river.

7. Cooperating agencies operating nurseries are urged to select, and test by outplanting, southern pine seedlings of superior characteristics (e.g. best 1/100 of 1%) from lots of seed of given size and weight for the purpose of determining the probability for making superior selections in this manner. This project is recommended as one which is available for immediate tests to determine possible superior strains.

Geographic Strains

W. H. Fischer, Chairman
P. C. Wakeley
A. C. Shaw
C. F. Korstian

Superior Phenotypes

E. J. Wiesehuegel, Chairman
G. H. Hepting
"Lefty" Easley
C. E. Clapp
D. J. Weddell
Jack T. May

Seed Source

F. M. Cossitt, Chairman
R. T. Clapp
W. K. Beichler
P. R. Wheeler
P. T. Lannan

Hybridization

A. D. Folweiler, Chairman
K. W. Dorman
Michel Afanasiev
C. M. Kaufman

FOREST GENETICS MEETING, ATLANTA, GEORGIA, JANUARY 9 AND 10, 1951

(J. Herbert Stone)

Welcome to this first conference on forest genetics to be held in the South. The interest that has been exhibited throughout the South in this conference has been surprising. When this conference was first discussed, we thought that perhaps 25 or 30 people, with special interest in the field of genetics, would wish to attend. However, when we began to explore the field of possible interest, we found that our estimate was considerably under and plans had to be adjusted to meet the expanded interest.

Purpose of the Meeting

The purpose of the meeting, simply stated, is to assess the status of our knowledge of genetics as related to trees and to determine the status or extent of the application of this knowledge. I have hopes that this meeting can give substance to the role which practicing foresters can and should play now and in the future in applying the principles of genetics to forest management. Out of our discussions, I am sure, can come some leads to the course which research in the field should take, and the part each individual and organization can take.

Importance of this Conference Now

My purpose on this program, however, is not to dwell further on the objectives of this exploratory conference, but rather to suggest the relationships of efforts in the field of genetics to the present international situation.

We are in a period of national emergency. No one can foretell how long this condition may exist, but all the facts seem to point to a long, continued state of emergency and uncertainty. This country must bear a large and important part in arming the free countries of the world and building up a defense program which can meet any aggression. Our whole economy must be and is being put into gear to produce and maintain the sinews of war. Our domestic economy will, no doubt, feel the pinch. Certainly, throughout this effort to rearm and to mobilize to meet the threat of aggression, our forests will be called upon to do their part. We will need increasing supplies of wood for pulp; we will need lumber. Our forests must provide these things. Pressures on them will increase. Since the emergency promises to be of long duration, foresters have a challenge to make our forests produce, and the responsibility to maintain our forests in a condition to meet an extended pressure for products to meet the national emergency. In addition, we must do our part to provide an abundance of forest products for the Nation's peacetime economy. A strong natural resource base is a bulwark to a free economy.

Forests are not built in six months or a year as you folks all know. Certainly we would be remiss, however, if we did not take the leadership in bringing to bear in our planting programs the scientific knowledge we now possess and in extending research in this field. Our forest planting must go ahead in order that we may be prepared to meet emergencies of the future. Our job is to grow the maximum amount of best quality timber that we can. We must apply scientific principles to the planting and the nurture of these crops. Our fund of information is all too limited, but we do know some things and those things we must get into practice and our research program must be geared to finding out the facts that are needed to make our planting programs, as well as our cutting practices, best serve the country's welfare present and future.

We, as individual practicing foresters, will have to face the question of how fast we can apply the principles which are shown to be desirable. I am sure we will not get to heaven in one jump, but neither will we make progress toward a goal that we do not have definitely in mind and for which we are not making effective plans. Personally, I believe that there will be many things that every practicing forestry organization or individual can do.

It is indeed timely that we have a conference of this sort from yet another point of view. In the last five years the number of trees being planted in the South has increased many fold. The number of trees produced and distributed throughout the South last year was something over two hundred million. That figure can be expected to increase behind the drive of such organizations as the Georgia Bankers Association and other agencies of that nature that are pushing the planting of forests all over the South. The Fulton Bank program, backed by the Georgia Bankers Association, and carried out by the multitude of country banks throughout the State of Georgia, are looking forward to a planting program in the next five years involving ninety to a hundred million seedlings annually. In a program of that sort the application of principles of genetics can be of untold value to the country in the future. It is high time that we made preparation to apply this scientific knowledge to strengthen the natural resource base on which our country's welfare will rest in the future. I think this conference is timely; indeed it may be too late. I believe that there are many principles which can be put into effect which will not increase the drain upon the manpower or equipment which may be needed in other phases of our economy. I do not believe our country can afford to set aside a planting program, and, particularly, not to apply the best known principles to that planting program during this grave period of national emergency.

Conference Action

Later today the program makes provision for the organization of four working committees. I hope that these working committees will find it practicable to suggest clearly the role of practicing agencies in helping to make the South's planting program contribute to the national need. I hope that they will point out the things that each organization or individual can do to put into practice the knowledge that is now known and I hope they will also point out the way in which these agencies can help to further the great research program which needs to be carried forward at an accelerated pace.

The second important task that I hope the committees will point up is the need for research. How should our research programs be strengthened? What need for correlation of these programs is there? How should research efforts be distributed between the various agencies working in this field.

Possibly there are other ways in which these committees can lay the framework to speed up and guide action in the field of genetics, but these are some of the things which seem to me important and which I hope we will see emerging from the deliberations of these various committees.

OBJECTIVES AND SCOPE OF RESEARCH IN GENETICS OF SOUTHERN PINE

By

I. T. Haig, Director
Southeastern Forest Experiment Station

Introductory Remarks

It is indeed a pleasure to see a group of this size, representing a cross section of the leading forest interests and agencies in the South, gathered together to discuss a topic as technical and of as long range a character as forest genetics--southern tree improvement. To my knowledge, this is the first meeting of its kind in this area.

If we are successful in making a beginning in tree improvement-- and like all essentially pioneering efforts the beginning is certain to be difficult, our progress slow--the potential contribution that superior trees could make to the productivity of southern forests may well make this meeting in time one of the major milestones in southern forestry. Your attendance here today, the widespread interest it indicates, argues well for the success of this effort.

I think we are right to look forward with optimism. As all of us realize, the development of superior plants and animals through introduction, selection, and breeding is one of the great achievements of American agriculture. Poultry that produce more eggs, pastures that produce more beef, better wheats that are hardy and disease resistant, hybrid corns, hybrid cottons, hybrid tobaccos, these and many other products of the breeder's art are now commonplace in the agricultural world. Agriculture's remarkable production record over the past decade, a record of higher yields with less labor and little or no more land, is due in no small part to superior plants and animals, the results of introduction and breeding. What farmer, except perhaps the poorest and most shiftless, would now plant an unimproved variety of wheat, or potatoes, or tobacco, or cotton--if indeed the seed of unimproved varieties could be obtained at all?

Yet, as we know, how different it is in forestry. Though we are now planting annually over 200 million trees in the South alone, few of these trees--for all practical purposes none--are of superior or selected stock. Most of our tree seed is undifferentiated except by species, without distinction as to race, type, or even point of origin.

Yet increasing knowledge of natural variation, including knowledge of racial strains varying widely in growth rate, form, hardiness and wood quality; the occurrence of hybrid vigor; the possibilities offered by interspecific crosses, the existence of polyploids among trees; all promise the possibility of results with trees equal to those obtained by breeders in other plant fields. Admittedly, the difficulties are many and formidable. Yet with all of these, and it does not seem necessary to review them here, I doubt if we can continue to justify, as professional foresters, the planting of unselected, unimproved trees on hundreds of thousands of acres in the South; in delaying any longer the initial steps necessary to take advantage of at least the preliminary improvements well within our grasp. Certainly we in America are already falling behind the Europeans in the use of superior seed and stock, though their knowledge is essentially no further advanced than our own.

What Can We Do Now

The objectives and scope of research in forest genetics in the South should ultimately be very broad--the production of superior trees for our region and climate--trees superior in growth rate, quality, disease resistance, naval stores production, and numerous other tree characters of biological and economic importance. At this working conference it is hoped that we can review present knowledge, outline a practical program for southern tree improvement, and plan for necessary cooperation and coordination. For practical reasons it might be well to focus our attention on the southern pines, with special emphasis on superior pines for planting.

Along this line could we not, now, take the following steps:

1. Insist on planting stock grown from seed of known and local origin. Comparable demands are commonplace with farmers with crop seed. Farmers are conscious of hereditary values and the seed industry is organized to supply them with stocks of known genetic quality. The same should be true in forestry. If seed and planting stock of known origin costs something more than seed of unknown origin, be willing to pay the difference. There is every indication that reasonable additional costs will be amply repaid.

2. Institute better methods of seed collection. Seed collections are now often made from trees and stands chosen solely for convenience in collecting and transporting. Indeed, the natural tendency is to make collections from recent fellings or from isolated broad-crowned, abundantly flowering trees where cones are easiest to reach. Collections, without control or mother tree or collection areas, involve a very serious risk of getting seed with bad hereditary properties, resulting in poor future timber production. In Sweden collections made in this way have already resulted in serious deterioration in plantations in northcentral Sweden, leading many owners to abandon their reforestation programs. It is a fair bet that many of our present plantations will also be somewhat disappointing due to the dysgenic character of past seed collections. Certainly we should not delay in improving our methods. This may require State seed collections, or strict State control of tree seed collecting.

3. Organize a survey to identify stands and trees of superior vigor, form, and other desirable quality. For the present this might be restricted to pines, though work should begin soon with other species. The U. S. Department of Agriculture sponsored such a survey of superior germ plasm for all crop plants and animals over 17 years ago. Such a survey would be aimed at locating superior stocks for seed production and breeding.

Superior (elite) trees and stands should be preserved, preferably by direct conversion to seed orchards or by vegetative propagation in orchard form in State arboreta or similarly suitable places. Plantations now reaching seed-bearing age offer a particularly attractive source of identifiable superior germ plasm. Progeny from elite trees and stands should be tested in tree shows, i.e., by planting in small groups with average stock for comparison. The experience of the State agricultural colleges in handling and testing breeding stock in agriculture and horticulture would be a great aid in such tasks. Here is a chance for State agencies to expand their forest research, admittedly too small in the past, in a useful and challenging field. Someone should be responsible for collecting in a genetic arboretum representatives of the principal races of the native trees of the South, together with closely related species and exotics of probable value in the region, in a tree breeding program. Such a collection would have immense and irreplaceable future value. Here again an endowed, educational, or State agency might well take the lead. Amateurs, universities, foundations, State agencies, the Federal Government, and private forestry societies might all well contribute to such a program. In Sweden, it is interesting to note, some of the most effective work is now being carried out by the "Society for Practical Forest Tree Breeding," an association of several middle and north Sweden forest industry companies.

4. Stimulate an adequate controlled-breeding program similar in general outline to that carried on with other plant and animal groups, but omitted or badly neglected so far with trees. Such a program should involve cytological studies and studies of vegetative propagation, as well as controlled breeding experiments. Most of these things could be undertaken on a small scale if reasonable continuity and preservation of breeding stock could be assured.

In summary, the difficulties in any program aimed at producing superior trees for planting are admittedly great. But we now have available tools formerly lacking, better knowledge, better methods of grafting, seed stimulation and seed storage, and maturing plantations as a source of identifiable superior trees. And the way to begin is to begin. Some immediate steps can be taken now without great difficulty if the cooperative effort of existing agencies can be secured. The potential gains are so promising that we should begin now to produce "Superior Pines for Planting."

Possibilities of Tree Improvement as Indicated By Developments in Other Fields[1]

C. C. Murray,
Dean and Director
College of Agriculture
University of Georgia.

Let me express my appreciation for the opportunity of appearing on your program here today to discuss some of the possibilities of tree improvement as indicated by developments in other fields. Development of the science of plant breeding really antedates Mendel and the workers of this period. It is an applied science that is carried out efficiently only through the application of other basic plant sciences. The rapid increase in the knowledge of genetics since the rediscovery of Mendel's laws of heredity in 1900, and the application of these laws to plant breeding, were essential steps in the development of plant breeding as a science. The contributions of cytogenetics in recent years have furnished in many cases a clear picture of genetic relationships based upon differences and similarities of chromosom morphology, structure, and function. Many economic plants are polyploids and a knowledge of chromosome numbers, pairing behavior, in crosses and gene differences among related species and varieties is essential in building new varieties of plants with the characters designed by the grower and consumer. Physical and chemical methods of inducing changes of chromosome numbers and structure and of inducing gene changes are being developed. Satisfactory techniques for inducing polyploidy in species and hybrids are available for certain types of plant breeding.

In order to evaluate a variety which has been developed it is necessary to compare it with varieties of known performance. The comparisons made by the plant breeder are extensive and frequently only a few replications can be grown. The development of adequate statistical methods has aided greatly in making reliable comparative trials. Experimental methods of making reliable comparisons are one of the tools of the plant breeder.

Methods have been devised in many cases for differentiating quality for a determination of the relative value of different characters, including chemical properties, make it possible under conditions of control pollination to select for the characters desired. In problems of breeding for disease resistance a knowledge of genetics of the pathogene is as essential as that of the crop plant itself. With each individual plant, information regarding available varieties, their characters, and their wild relatives furnishes a basis for the combination of genes desired by the breeder. For diseases caused by pathogenes it is equally important to know the probable mode of origin of new strains of the organisms, and the number, distribution and genetic nature of the strains present in the region where the crop plant is to be grown.

A wealth of information is available regarding the genetics of crop plants and the progress which has been made by the application of genetics to their breeding and improvement. It seems, therefore, unwise to attempt here to make a complete review of the present status of the progress which has been made in connection with the breeding of certain species. The literature is voluminous in regard to this and I shall, therefore, attempt now to cite what I think to be some examples of progress that have been made by plant breeders and try to point out what the opportunities appear to be for the development of superior varieties, hybrids, and strains of forest trees by scientific breeding methods. However, before the citation of these examples, I should like to make a few observations concerning what I think to be of fundamental importance at this point. Plant breeding today is more than an art. In order for a plant breeder to be productive and efficient in his work it is necessary that he have fundamental training in the biological sciences. Some of the more important phases of this training may be summarized as follows:

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[1] Delivered to conference on Forest Genetics Research in Southern Pines, Atlanta, Georgia, January 9, 1951.

1. A knowledge of genetic and cytogenetic principles.

2. A knowledge of the characteristics of the crop to be improved, including its wild relatives.

3. Information regarding the needs of the grower or the producer.

4. A knowledge of special techniques adapted to the solution of the particular problem or problems at hand.

5. A knowledge of the principles of field plot technique.

6. A knowledge of the principles involved in the design of experiments and the statistical reduction and interpretation of data.

I should like now to discuss briefly some of the developments which have been made by plant breeders in an effort to indicate to you what may reasonably be expected in the field of forest tree improvement where the tools of the geneticists, cytogeneticists, etc. as well as the statisticians are brought to bear upon the problem of forest tree breeding. Several years ago a cooperative project between the University of Minnesota and the Office of Cereal Investigation of the United States Department of Agriculture was initiated for the purpose of developing a variety of spring wheat which was resistant to stem rust. Personnel who cooperated on this project consisted of agronomists, plant geneticists, chemists, plant pathologists, etc. In the studies, artificial epidemics of stem rust were developed both under field conditions and in the greenhouse. During the early period of this study resistant vulgare or common wheats were unknown. The development of rust resistant strains was accomplished by obtaining resistance from the emmer group and by combining this resistance with the desirable agromonic characters of vulgare or common wheats through a series of crosses and selections.

Much remains to be known about rust resistance in wheat but many problems have been solved. Some of the steps leading to our present knowledge may be cited here:

1. The mode of inheritance of particular types of reaction to stem rust have been determined both in the greenhouse and in the field. The most important and practical result of these studies is the conclusion that resistance to all races of stem rust of wheat in the stages from heading to maturity may be dependent upon only a single or a few genetic factors.

2. The pathogene causing the disease is composed of numerous forms, which we call physiologic races that can be identified by their manner of reaction with a series of wheat varieties and species known as differential host, this separation being made primarily on the basis of seedling reaction. For example, a wheat variety resistant to a particular race of rust in the seedling stage is resistant to this same race in all stages of plant growth under field conditions. Physiological resistance in the seedling stage is of such a nature that wheat may be immune from one and susceptible to another. An illustration of that of Kanred wheat and some hybrid derivatives having it as an ancestor are immune from certain races and highly susceptible to others. This knowledge explains the reason why Kanred wheat and derivatives may be highly resistant in one season and highly susceptible in another. A knowledge of the cause of resistance has been of importance. Thus the resistance of Kanred is physiological and acts only against particular races of rust. A second type of resistance under field conditions to many races of rust as the plants approach maturity, called mature plant resistance, appears to be simply inherited. The exact cause of this type of resistance is unknown. Some have suggested that morphological and functional causes may be responsible. Others have given evidence indicating that this doesn't seem to be the explanation. Mature plant resistance is inherited in some cases in a simple Mendelian manner. It has been learned also that extreme conditions of environment may cause an apparent breakdown of resistance to a particular disease. For example, a plant genotypically resistant to stem rust, if infected with loose smut, may be completely susceptible to rust. This conclusion seems essential in a logical viewpoint of disease resistance in plants. No one expects that a potentially high-yielding variety will give high yields under unfavorable conditions. Extreme conditions of environment may strongly modify reaction to disease by modifying the character, that, under normal conditions, is responsible for the resistance to that particular disease.

Another variety wheat, Thatcher, which was first introduced in the spring of 1934 has been one of the most widely grown stem rust resistant wheats being the major spring wheat grown in the eastern and central sections of the spring-wheat area. It is also extensively grown in Canacian provinces where stem rust has been severe. It withstood in excellent fashion the stem rust epidemic of 1935, 1937 and 1938 when susceptible varieties of spring wheats were severely injured. Thatcher excels in yielding ability, strength of straw, and milling and baking quality but is somewhat less satisfactory in weight per bushel than some other varieties, partly because of its small size of seed and its susceptibility to scab and leaf rust. The latter diseas was epidemic in 1938 in the spring-wheat area.

I should like to use one other example of the progress that has been made in the breeding of wheat. McFadden in 1930 was the first breeder to develop common wheats having near immunity to stem rust. He produced two wheats, Hope and H44, with excellent resistance, or, as I said practical immunity to these diseases. Neither of these wheats, however, was entirely satisfactory in other characters. The resistance of Hope and H44 to all rust racc in the field under normal conditions in North America is dependent upon one or two major genetic factors for resistance. Most of the more promising new spring wheats have Hope or H44 in their parentage. Many plant breeders develop varieties and strains which are highly resistant or almost immune to diseases but are lacking in other desirable characteristics. It is presumed that this same difficulty will be, if it has not already in some cases, encountered by plant breeders and geneticists who concern themselves with the problem of improving forest trees.

I should like now to comment somewhat briefly on the progress that has been made in corn breeding. Several years ago the viewpoint was expressed by various writers that corn hybrids for different regions of the corn belt would have far-reaching effect on the agriculture of the United States.

The hybrid, Burr-Leaming, was first distributed in Connecticut in 1922, but the acreage grown of his hybrid was very small. The first distribution of hybrids in the corn belt occurred from 1932 to 1934, and in 1938 and 1939 from 15 to 25 million acres were planted to hybrid corn, and increased production during this period of from 100 million to 150 million bushels of corn over what would have been /obtained if hybrid corn had not been available. Many agronomists believe that there will continue to be a rapid increase in the use of hybrid corn in the years to come until the greatest part of the acreage of corn in the United States is planted in hybrids. As a matter of fact, we have already reached this stage in the corn belt - in many states from 95 to 98% and in some, I suspect, today approach 100%. In the southern region progress has been somewhat slower in the development of hybrid corn. It is not because, however, that our research agronomists, geneticists, and plant breeders have not concerned themselves with this problem. As a matter of fact at several of the Experiment Stations in the southern region hybrid corn breeding programs were begun between 1920 and 1925. We have in the southern region, however, somewhat more difficult problems and conditions than in the case of the corn belt. This is the reason that the development of corn hybrids in the south has been somewhat slower. For example, in the southern region the problem of insect control, particularly the weevil, has been most difficult to deal with. It is a fairly simple matter for a corn breeder to develop a hybrid that will give exceptionally good yields that will, as a matter of fact, out-yield by 25 to 30% that of open pollinated varieties. However, we find that to get satisfactory resistance to the ear rots as well as stalk and leaf diseases and to produce a hybrid with satisfactory standability is a most difficult job. Widespread interest in hybrid corn is due primarily to the superiority of hybrids over normal varieties in a number of characters.

Although higher acre yields are important, other improvements as I have already indicated are equal and perhaps of even greater value. Ability to withstand lodging, for example, and resistance to smut, ear rots, stalk rots, as well as insects is of major importance. The development of drought resistance has been studied very much, particularly in the corn belt area and much remains to be accomplished on this problem.

In the development of hybrid corn Mendelian principles have been used directly. A standard technique of breeding has been developed based on the direct application of the principles of genetics. Intensive studies of inbreeding and cross breeding were started by E. M. East at the Connecticut Agricultural Experiment Station and G. H. Shull at Cold Spring Harbor in 1905. Many investigators have taken part in studies of inheritance in maize. The fundamental principles have led to a sound basis for scientific improvement in corn, a field in which a considerable number of investigators devote all or part of their research efforts. Some of the more important principles leading to the present methods of corn breeding I would like to mention here, although corn breeding is not directly analogous to the breeding of forest trees. Nevertheless, there is much in common, particularly from the standpoint of reproduction. As you know, in the case of corn 98 to 100% of it is cross pollinated and while I am not too familiar with this I understand there is great similarity to pines.

I should like now to mention some other important principles which have led to the development of present methods of corn breeding:

1. Continued self-pollination in corn leads to the production of relatively homozygous types that are in general less vigorous than normal corn. Crossing inbreds restores vigor. Some F_1 crosses are more vigorous than normal corn; others are less so.

2. Crosses between inbreds are difficult to use in commercial seed production, since the yield of seed per acre is low. This difficulty has been overcome by using for commercial production crosses between single crosses.

3. Hybrid vigor in corn and in other crop plants has been placed on a definite Mendelian basis. It is a result of partially dominant growth factors. Many genes are involved in growth and vigor, and consequently linkage makes it difficult to combine all of the desirable genes in one inbred line.

4. Some inbred lines have much better combining ability than others when tested in comparable crosses. By crossing a group of inbreds to be used in a definite breeding program with a variety and by testing the inbred-variety crosses in yield trials, the better combining inbreds can be isolated and the less desirable discarded. As a matter of fact, this method has been widely used by corn breeders.

5. The combining value of inbred lines in a double cross can be predicted from yield trials of the appropriate single crosses.

6. The ease of commercial production of double-crossed seed is dependent to a considerable extent upon the vigor of the inbred lines as well as the yielding ability of the single crosses used in the double cross. Improved inbred lines of corn can be bred by the same breeding methods as used in the production of improved varieties of self-pollinated plants, although it is necessary to control pollination by appropriate selfing and crossing in carrying out the program. This, obviously would be true in the case of pines.

7. The principles of corn breeding that make possible the utilization of hybrid vigor are dependent upon an understanding of genetic principles and their application of corn breeding. This knowledge has made possible to a considerable extent the standardization of corn-breeding techniques.

I should like now to refer to some of the progress which has been made in the breeding of improved varieties of oats. There are 3 important diseases of oats. They are stem rust, crown rust, and smuts. Resistance to disease, therefore, as well as resistance to cold injury are two things which are emphasized very strongly in the breeding work on oats. Of course there are other problems such as the stiffness of straw. This has come into prominance in recent years because of the fact that the most of our oats as well as othe types of small grain are presently harvested with combines. Therefore, it is necessary to leave the material in the field until it is sufficiently dry for thrashing.

Crown rust, for example, is one disease which has been singled out and worked on by a large number of plant breeders. Although some varieties have long been available which show some resistance to crown rust the introduction of Victoria from South America and Bond from Australia have furnished a basis for breeding of resistant varieties since both Bond and Victoria are resistant to many races of crown rust. By using Victoria as one parent in crosses with susceptible varieties Smith, in 1934, concluded that resistance was a partial dominant in F_1. However, infection made it impossible to decide the number of factors involved. Stanton, later in 1936, indicated a single factor pair with resistance dominant. Inasmuch as good success was obtained by using Victoria as one of the parents, breeders generally throughout the country obtained satisfactory resistance to practically all of the physiologic races of crown rust. Everything seemed to be moving along nicely until a few years ago a disease known as blight or Helminthiosporium Victoria came into the oat area. It was found then that the new hybrid oats of Victoria origin were extremely susceptible to Helminthiosporium. This made it necessary that breeders seek out new germ plasm for resistance to Helminthiosporium. While they were doing this it was necessary to dig out some of the old varieties of oats which we had grown several years ago because these happened to carry satisfactory resistance to Helminthiosporium. To make a long story short, fairly satisfactory progress was made in a few years in the development of varieties having satisfactory resistance to Helminthiosporium because of the wealth of genetic material which was in the hands of the breeders. Then when it looked like we had Helminthiosporium and crown rust licked, race 45 of crown rust came into being which was a new physiologic race of rust and this new race did tremendous damage to a large number of varieties which were in rather general production. At this time now, oat breeders are generally emphasizing resistance not only to these diseases which I have mentioned but are giving particular attention to the development of varieties which are resistant to the more important physiologic races of rust as well as smut. The smut problem was fairly easy to lick. It wasn't difficult for the breeders to find strains or species of oats which carried satisfactory resistance to smut. As a matter of fact the Coker Pedigreed Seed Co. along about 1930 or 32 had developed oats with excellent resistance to smut.

Thus far, I have confined my remarks rather generally to the end products of plant breeding research. These contributions didn't just happen by chance. As I indicated earlier the science of plant breeding is based upon the fundamental biological sciences. I would like, therefore, at this time to emphasize the need for the accumulation of certain fundamental information. By this, I mean developing a program of basic research in forest-tree genetics, which to the layman might not appear to be of any practical value, but will furnish the storehouse of knowledge upon which future forest-tree breeding programs may be developed. The reason for this has been pretty well indicated in certain crops and crop breeding programs. For example, the work of Beasley in interspecific hybridization of cotton which was pure science and which furnished the foundation to develop practical breeding programs to increase fiber strength is an excellent example of the point which I am trying to make. Dr. Beasley was interested from a fundamental point of view of the origin or development of our so-called American upland cotton. Much had been written by scientists relative to how this American upland type originated. Dr. Beasley in his work made a very careful cytological examination of the chromosomal complement of a large number of wild as well as cultivated species of cotton consisting of the old world types having 13 pairs of chromosomes as well as the new world forms illustrated by the type American upland having 26 pairs of chromosomes. To make a long story short and not to take up too much of your time here with details, I might say that upon a cytological examination Dr. Beasley found that the American upland chromosomal complement could be divided into two parts. One part or genome as it is commonly called consisting of 13 pairs of chromosomes had upon observation considerable similarity to one of the wild 13 chromosome American cottons. The other half of the genome had certain appearances which led Dr. Beasley to believe that these 13 chromosomes were very similar to one of the Asiatic species of cotton. Dr. Beasley, therefore, attempted to hybridize the wild American with the Asiastic 13 chromosome cottons. This, he found difficult to do but was successful finally in accomplishing a cross. He was able then by the use of colchocine to double the chromosome number of the new hybrid which was found to be perfectly normal and fertile. He studied extensively the chromosomal behavior of this synthetic hybrid having 26 pairs of chromosomes which is the same as American upland cotton. He found, for example, that the behavior of the chromosome in the synthesized hybrid was for all practical purposes identical with that in the normal American upland cotton. This gave extremely strong evidence that this is the manner in which American upland cotton originated. Dr. Beasley reasoned, therefore, that on the basis of chromosomal behavior in the synthesized hybrid that it should therefore cross readily with American upland cotton. He was able, consequently, to make the crosses at will between American upland cotton and the synthesized hybrid and without laboring the point further this, while the approach was one of pure science led to what is accepted to be, by most people, an explanation of the origin of American upland cotton. Other work of a fundamental nature which has been extremely productive might be mentioned. For example, the work of Reeves and Manglodorff with regard to the origin of corn and how the genetic and cytogenetic knowledge contributed by them is used as a basis for the improvement of corn.

Returning again to cotton I should like to point out one or two things which are receiving major emphasis now. The work of Beasley opened up a new era for the cotton breeder. It made available material which he, up to that time, had not been able to use in a practical breeding program. With the developmentment of the passage of the Research and Marketing Act in 1946 and the implementation of a regional research program on cotton genetics there has been developed a project which emphasizes the genetic and cytogenetic approacl to the problem of cotton breeding. Research agronomists have been able to accomplish gene transfers from wild cotton into upland types and we are at the present time in the process of developing new varieties of cotton which may not yield appreciably more than some we now have but which have fiber of a tensil strength greatly beyond that which has ever been known in present day cotton. Some of these desirable genes or blocks of genes have been obtained from wild species which to the ordinary person would never have been thought to have anything of a worthwhile nature in them. In the case of cotton we not only have varieties which have good resistance to fusarium wilt, bacterial blight, angular leaf spot, and a number of other diseases but we have varieties of cotton which are far superior in regard to spinning performance than any that we have ever had to date. Breeders now are beginning to give consideration to the breeding of varieties of cotton, the fiber of which will be particularly suited to specific end uses.

I have had the opportunity of talking with Mr. Dorman and observing photographs of various selections of pine trees that had been made and also various hybrid combinations which to me indicate hybrid vigor of a magnitude comparable to that and perhaps even greater than we have been accustomed to thinking in terms of corn and some other crops which have demonstrated excellent heterosis or hybrid vigor. I believe therefore, that we are on the verge now of getting into a forest-tree breeding program in which we will attempt to emphasize resistance to diseases generally, rate of growth, the time at which trees may reach marketable size, development perhaps of varieties or types of pines which will be used specifically for naval stores. I think, too, that we shall give emphasis not only to the rate of growth and the amount of gum produced from trees but we shall also give consideration to the matter of the quality of lumber and other products that might be made from pine trees.

I should like now to make some observations with reference to some of the problems which I think you people will be concerned with in the conduct of a forest tree research breeding program. First, I assume that it is needless to point out that forest tree genetics are no different in principle than the genetics in any other organism and that the program, therefore, initiated for the purpose of improving trees should be based upon sound genetic and plant breeding concepts and theories.

As a layman, from the standpoint of the group assembled here today, I would like to say that it is encouraging to me to note that the public generally is now looking upon our timber resource with much more interest than has been demonstrated formerly. For example, many people are aware of the fact that a large proportion of the land now only in our state here but in other southeastern states is occupied by timber. Furthermore, many farmers now are becoming concerned about protecting their timber resource from fire and other ravages and with the assistance of forestry personnel, thinking in terms of managing their tracts and marketing their timber in a manner which will bring them the most income from their woodland. I believe, therefore, that now is the time at which we should attempt to initiate a good sound forest tree breeding program and to begin with, inasmuch as the pine is a species which is perhaps more widely grown and contributes more from the standpoint of lumber byproducts, that a good species to begin with would be the pine. Of course, one reason why many people have not become so interested in the breeding of trees and in the planting of trees, and in reforesting some of our gullied eroded land, is because of their short-sighted viewpoint. Many people assume the attitude that, well, this is a long range program and is something that will extend quite beyond my lifetime and therefore I'll let somebody else concern themselves with this problem. During recent years as I have already indicated to you, people now are beginning to do somewhat more long range planning than has been true in the past. Obviously, I am not in a position to suggest to such a group as this what a forest tree breeding program should be like. There are other people on the program here who are in a position to discuss intelligently what a forest tree breeding program is like, some of the problems that will be confronted and some of the needs personnel-wise, material-wise, and financial-wise, in the conduct of such a program.

Im speaking of the program, I am glad to see provision has been made for detailed study on some of the fundamental problems by 4 committees. For example, you have a committee to give consideration to geographic strains, another committee on natural variations and selection of superior phenotypes, another committee concerning itself with the stimulation of seed production in superior trees and then another committee on hybridization. These committee assignments, I believe, cover the major problem areas that you should concern yourselves with at the present time. Having spent some years as an agronomist and a plant breeder, I am familiar with a number of the problems with which a plant breeder becomes involved. And the problems have certain common characteristics regardless of the crop in question. I mentioned to begin with some of the tools that the plant breeder has used and which have been responsible for his increased productivity. I mentioned genetics, cytology, and statistics. In recent years plant breeders and geneticists for that matter have concerned themselves very much with the field of statistics or sometimes referred to as biometry. There are a number of reasons for this. In the first place, genetics is a science which is based or predicated pretty largely on mathematics, ratios, and so on, and we have had some new tools placed in the hands of geneticists and plant breeders in recent years by mathematicians which make it possible now for the plant breeder to fractionate or break down the total variance of a population into its various component parts, that is, that which is due to environmental effects and that which is ascribable purely to hereditary factors. This has enabled plant breeders in recent years to be, as I have said, much more productive. In the last 15 years or so, progress in plant breeding has not been so spectacular as it was in former years. As a matter of fact, most of the problems with which the plant breeder is faced today are complicated from the standpoint of inheritance. They are commonly referred to as quantitative factors, and therefore are much more difficult to deal with and to get into a fairly stable condition, genetically, than is true of a situation where you have only one or two or three genes.

In addition to the necessity of a complete knowledge of the genetics of the species involved, it is necessary to develop methods of making crosses, handling, and growing out material from crosses and selections, etc. Equally as important from the standpoint of plant breeding is a good efficient method of testing progenies which are isolated either by selection or progenies which have been originated as the result of hybridization and subsequent selection. And a system must be developed for growing and testing the F_1 and F_2 back cross and subsequent generations. This is just as important as making the cross because a good job must be done in testing the selections in order to make the best use of the hybrid material. Evaluation of material is one of the most important phases of breeding. No doubt every breeder has thrown away valuable material because of inadequate testing. Conversely, material of questionable value is carried for the same reason. The breeder must have tremendous numbers in order to secure all possible genotypes of value. For this reason you must discard lots of materials. The system of testing should be as good as possible so that he can do an effective job in evaluating progenies. At the same time the breeder must be abreast of the times and be able to predict segregates and strains of possible future value as well as of immediate importance. Thus, it is seen that the breeder must be well trained, persevering, observant in his habits. Plant breeding is no longer looked upon as an art and entrusted to the lucky guy who happens to be at the right place at the right time. In conducting a testing program it is necessary to use a design that will be efficient in measuring the factor or factors or variables on which it is designed to obtain data. I shall not attempt here to get into a discussion of experimental designs. I would however, like to point out that as we initiate and get a tree breeding program under way that it will be necessary to provide facilities for the testing of a large number of seedlings in sufficient number and with sufficient replication so as to measure differences of economic value. With other crops and I am sure it will be equally true in the case of forest trees, it is necessary to conduct such performance tests under conditions where it is anticipated that the new strain for hybrids may be grown. This makes it necessary to give careful consideration to the selection of sites for the conduct of such performance tests. Inasmuch as a forest tree breeding program will involve the handling of genetic material which will have regional potential promise it will be necessary in your case, as it has been with agronomists in the case of plant breeding, to plan a cooperative testing or performance program with personnel in the several southeastern states and also to take into consideration the variation of soils and climate conditions which occur in the different states. This will be necessary because with the large number of selections or strains, varieties or hybrids that will ultimately come out of the breeding program they of necessity will have to be tested under a good cross section of conditions, which are typical of the area in which it is contemplated that the species may be grown. Of course, the number of seedlings that will be handled in such a testing program can be materially reduced by the development and utilization of greenhouse and nurseries at selected areas. Take for example, the technique which is now used by cotton breeders as an example. Particular attention, as I cited a while ago, is now given to fiber strength in cotton breeding. There has consequently been developed fiber laboratories at most of the experiment stations where cotton breeding research is under way. The cotton breeder, therefore, has technicians at his disposal who are in a position to use machines and instruments which have been developed in recent years so that he can get a good estimate of fiber properties of several thousand selections which he may make in a given season. On the basis of these data he is in a position to eliminate, on the basis of fiber properties, a large percentage of his selections without even having to go to the trouble of growing them. With such a facility a cotton breeder, therefore, has pretty good assurance that any selection which he makes in the field and which passes satisfactorily his criteria for fiber properties will ultimately be useful in his breeding program. Those strains or selections surviving the testing program in the cotton fiber laboratory are grown in the field under field conditions for the purpose of observing agronomic characters and resistance or susceptibility to insects and diseases. Those which survive 2 or 3 years testing under field conditions then are multiplied and put into a new strains test. This new strains test is planted at several locations out over the state. Material which appears to hold promise in these new strains tests are put into what the breeders call advanced strains tests. At this stage of the breeding program material is exchanged by the breeders in various cotton growing states. This makes it possible for the breeder in the given state to get a good idea of how widely his strains might be adapted. Strains which appear to hold good promise in the advanced strains test are then put into a commercial test in which they are compared with commercial varieties all across the belt. It occurs to me that such a testing program will have to be developed in the case of forest trees. The difficulty that you will encounter is the fact that it will take quite some years later to get the data from forest trees whereas it can be obtained on an annual basis from field crops. In regard to this, however, I venture to predict that it will not be too long until techniques will be developed for estimating the quality of trees that may be expected from the standpoint of its use as a source of pulpwood, lumber, and for naval stores production. In the case of cotton we have established a high degree of correlation between 5 to 6 cotton fiber properties and spinning performance. So it is a very simple matter to measure these fiber properties in the laboratory and when they are known for us to then predict spinning performance. I believe that such will be possible in the case of forest trees.

In conclusion, let me say again that I appreciate very much the opportunit of being with you here today and of saying something to you which I hope has been of interest. I am sure, however, that I shall receive, while I am with you today, more than I have been in position to give you. Personally, I think that the purpose of this meeting holds much promise and I believe, as I have already indicated, that we have reached the stage or point where some research must be initiated in the field of forest tree breeding in the southern region and which I am sure holds as much promise in this field as in that of any other.

Perhaps unwisely so, but I have nevertheless purposely avoided being too technical in my presentation. I would, however, at this point like to reemphasize something which I mentioned earlier. That is, in order for a forest tree breeding program to be productive it is going to necessitate the close cooperation and work of foresters, geneticists, cytologists, physiologists, as well as people in many other specialized areas. I am sure also that you people realize that in order to put the program in forest tree breeding over, that the public must be made aware of the potential benefits to be derived from such a venture. I am confident that the people of the industry realize the opportunity which lies ahead in this field and I am sure that they, along with others of us who represent public institutions and agencies of the Government, want to exercise every possible effort in order to get a good forest tree breeding program initiated, one which is well planned, and one which can be put on a sound basis, sufficiently financed over a period of years that will enable us to be productive. As I see it, we can no longer take for granted our timber and woodland resources of this country and consider them as expendable without regard to replenishing the species.

In conclusion, I should like to express my very keen interest in and the excellent opportunity which I feel exists in the development of a good forest tree breeding program. I think that it should be obvious to anyone who thinks about the problems involved in forest tree breeding should realize that there are just as great a possibilities for contributing to the national welfare with respect to this crop as has been demonstrated with corn, wheat, otas, cotton, as well as horticultural crops, a few of which I have tried to mention to you here today.

I hope very much that thus meeting will represent the nucleous or beginnin of a movement which may culminate in the development of a good forest tree breeding program because I have already indicated, we are devoting a larger percentage of our land to forest trees than any other single use. It also provides a large share of the gross income of the farmers of the southeastern states. Why then, should we not become concerned about making this resource more productive just as wehave become concerned about the breeding of superior varieties of crops, breeds, types, classes, livestock.

Thank you.

IMPORTANCE OF GEOGRAPHIC STRAINS[1]

By

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A geographic strain of forest trees consists of individuals which, because of their origin in some particular place, share certain inherited physiological tendencies that enable them to thrive better in certain locations than individuals of the same species from other places. The fact that these tendencies are inherited makes such strains a genetical problem. The often serious loss in thrift when the wrong strain is planted on a given site makes the problem economically important.

Geographic strains became a matter of concern rather early in the development of forest planting. According to Baldwin (1942), their importance was first expressed correctly by a Swedish author in 1769, and some experiments on the effect of seed source were a casualty of the French Revolution. Proof that geographic source of seed is of tremendous significance in forest planting is now practically world-wide. In the European countries in which forest genetics research has progressed the farthest, both hybridizing and the selection of superior individual trees has been done with careful regard to, and within the framework of, geographic strains. The progeny of even the most superlative tree in a given region may fail if planted somewhere else.

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[1] Presented at the South-wide Conference on Tree Improvement and Genetics at Atlanta, Georgia, January 9, 1951.

There is a voluminous literature on geographic strains of forest trees. Several general summaries of the problem, and most of the available results of studies of American species, are included in the literature cited in the supplementary notes.

I have personally seen striking variations in root habit in longleaf seedlings, directly attributable to Louisiana versus Georgia origin of seed. I have seen equally distinct variations in foliage development of longleaf seedlings, directly attributable to origin of seed on clay and on deep sands within sixty miles of each other. I have seen shortleaf seedlings from Pennsylvania and Texas seed, in the same bed in a Louisiana nursery, differ by 2 months in the time at which they completed growth in the fall, by 3 inches in average height in September and by 6 inches in November, and to a great extent in the development of secondary needles and winter buds. Regardless of any economic importance, such variations are evidence of geographic strains in southern pines.

At Bogalusa, Louisiana, in the winter of 1924-25, I saw the Great Southern Lumber Company plant 5,000 acres of loblolly pine--fortunately with stock grown from local seed. One year later the Southern Forest Experiment Station established a study at Bogalusa which has since shown that if the company had used loblolly seed from certain parts of Georgia or Arkansas, it would have lost over $100,000 worth of growth on its 5,000 acres during the first 22 years after planting. Few would question the economic importance of this difference between geographic strains.

The first 15 years' results of the Bogalusa experiment with geographic sources of loblolly pine seed have been published in the Journal of Forestry, and the results at 15 and 22 years are summarized in table 1 of the supplementary notes. The differences in disease resistance among the 4 geographic strains tested have been as noteworthy as the differences in growth. The trees from the one eastern source of seed (Georgia) included in the study have proved far more susceptible to southern fusiform rust than the stock from Texas, Arkansas, or local Louisiana seed. Infection of the Georgia stock continues annually. Infection of the other three strains ceased at an early age.

The weakness of this study is that it included only one species of southern pine, and tested this species in only one place. While it showed that the stock from local Louisiana loblolly seed excelled that from Georgia seed when both were planted at Bogalusa, it gave no clue as to which would be better if both were planted in Georgia, or elsewhere.

To remedy this defect, the Southern Station arranged, in 1935, with the help of federal, State, forest school, and industrial cooperators, a comprehensive study of longleaf seed from 11 sources, slash from 7, loblolly from 12, and shortleaf from 14. Seed came from as far north as Pennsylvania and New Jersey, as far south as northeastern Florida, and as far west as Arkansas and Texas. It was distributed to 12 different nurseries in this country for sowing, and surplus slash pine seed from 6 sources and loblolly from 11 sources was sent to the Union of South Africa.

The original plan was to plant stock from each seed lot at or near its point of origin and also at the point of collection of every other lot of the same species, but some lots were too small to permit this. Despite the best intentions, some of the experimental plantations were laid out poorly, some were correctly designed but failed to survive well, and others, initially successful, were injured or destroyed during or after the war by fire or hogs. For these reasons, only very meager data from the 1935 study can be presented here to supplement the results of the original Bogalusa study.

The best data, published by Sherry in 1947, were obtained in South Africa, where plantations had been established at 4 widely separated localities, at latitudes 25° to 31° S. (The seed had been collected at latitudes 30° to 38° N.) The average heights attained at 9 years in South Africa are given in table 2 of the supplementary notes.

In South Africa, loblolly pine developed differences in average heights far more striking than those shown in the original Boghalusa study. On the best of the 4 sites, average heights at 9 years ranged from 35 to 46 feet, depending on seed source. On the poorest, they ranged from 21 to 37, with the stock of least suitable geographic origin making only 57 percent of the height growth of the most suitable. In general, growth was better the lower the latitude of origin, but there were a few conspicuous exceptions. Seed from Onslow County, North Carolina showed superior vigor for its latitude of origin, and seed from the Kisatchie National Forest in Louisiana and from the Crossett Experimental Forest in Arkansas, showed inferior.

Slash pine from seed collected in the United States did not, in the South African tests, show evidence of geographic strains comparable to those found in loblolly. The greatest range in average heights of slash from seed source to seed source, in any one South African test, was from 36 to 40 feet; that is, stock from seed from the least suitable source made 90 percent of the growth of the most suitable. Little evidence of distinct strains has appeared in American plantations of slash pine stock from the same sources and from one more northerly (South Carolina) source.

After 13 years in the few undamaged or only lightly damaged experimental plantations in the United States, loblolly from the different sources varied much less in average height than it had at 9 years in South Africa. At Jasper, Texas, average heights ranged from 29 to 34 feet; the least well-adapted stock had made 85 percent of the height growth of the best adapted, whereas in South Africa it had made only 57 percent. At Athens, Georgia, average heights ranged from 31 to 35 feet. At Jasper, average height decreased much less rapidly with increasing northern latitude of seed source than it did in South Africa, and at Athens the trend of decreasing average height over latitude of source practically disappeared. At both Jasper and Athens, however, the relatively good performance of the North Carolina strain and poor performance of the Louisiana and Arkansas strains showed up as they had in South Africa, although somewhat less conspicuously. Even though they confirm the original Bogalusa study less strongly than do the South African results, these differences in growth in the American plots of the 1935 study keep the issue of loblolly seed source very much alive.

As in the Bogalusa study, conspicuous differences in fusiform rust infection were associated with geographic source of seed in the American plantations of the 1935 study. The North Carolina stock, for example, had 22 percent of all living trees infected at both Athens, Georgia, and Jasper, Texas. The South Carolina stock had 8 and 16 percent infected at the same two places. Two western strains, those from the Kisatchie National Forest in Louisiana and from Trinity County, Texas, showed only 3 and 1 percent infection, respectively, at Athens, and 7 and 2 percent at Jasper. These results parallel those from the Bogalusa study, in which the one eastern strain of loblolly (Georgia) was much more heavily infected than the three western strains (Louisiana, Arkansas, and Texas). But strains from northeastern sources, which were not tested in the original Bogalusa study, also proved relatively unsusceptible in the 1935 study. Virginia stock was infected only 4 percent at Athens and only 6 percent as Jasper, and Maryland stock showed no infection at either place.

In the earlier study at Bogalusa, and in both South African and American plantations in the 1935 study, loblolly pine from southern sources tended to outgrow, or at least to equal, that from northern sources. This may have been because the experimental plantations were nearer the Equator than was the middle of the range from which seed was collected, and in some cases nearer the Equator than most or all of the seed sources. An opposite tendency has appeared in shortleaf pine in the 1935 study, in Pennsylvania. Here, in both growth and survival, seed from the southern part of the species range has given less good results than that from the central part and both have done far less well than local, northern seed (Aughanbaugh, 1950).

In 1939 the Chiefs of the Soil Conservation Service and of the Forest Service, together with the Secretary of Agriculture, approved a Forest Seed Policy, binding upon all Bureaus in the U. S. Department of Agriculture and strongly urged upon all agencies cooperating with the Department. Its purpose is to prevent gross losses through use of tree seed of unsuitable geographic source. In simplest terms, it calls for use of local seed unless seed from some more distant source has been proved definitely better, and defines local seed as seed collected within 100 miles of the planting site and within 1,000 feet of the planting-site elevation.

Adherence to this policy should prevent many serious losses, such as that which the Great Southern Lumber Company might have incurred had it planted 5,000 acres with Georgia or Arkansas seed instead of with local seed in 1924-25. It is not always possible, however, to get the amount of seed needed, when it is needed, within 100 miles of the planting site. Some of the data presented here indicate that for many sites, slash pine seed (or even in some cases loblolly pine seed) from more distant sources may be just as suitable. In some instances it may possibly be better.

Where does all this leave us?

We know that geographic strains exist in loblolly, and probably also in longleaf and shortleaf. They are not wholly disproved in slash.

We do not know what has given rise to these geographic strains--whether differences in temperature, rainfall, day-length, or soil, or migration from different centers of botanical distribution, or long periods of exposure to different races of rust, or some combination of these influences.

We do not know, from field tests, where we may safely go for seed of any southern pine for use on any given planting site. The Department's Tree Seed Policy, although a laudable step in the right direction, is admittedly an arbitrary, makeshift guide. Its application may be unnecessary in some cases.

Barring total war, we may expect 20 to 30 years aggressive planting of southern pine--and then a marked tapering off. To avoid very serious economic losses, we must clarify the question of geographic source of seed for southern pine plantations as near the beginning of this 20-to 30-year period as we can.

What do we propose to do about it?

First, it is proposed to launch a new, comprehensive, cooperative study of geographic strains of the four principal southern pines, under the guidance of a committee to be set up at this meeting. The study should be carefully planned to permit useful generalizations concerning suitable sources of seed; to standardize choice of seed trees at the various seed sources; to standardize designs of test plantations; to permit early evaluation of results in terms of height and later evaluation in terms of yield and of disease resistance; and to minimize the burden placed upon any one cooperator. The plan, and negotiations for the establishment of the study, should be completed in ample time to make use of seed from the 1951 crop.

Second, it is proposed to distribute a simple plan whereby any interested individual can make an effective, independent, 1- or 2-acre test of the relative suitability of feasible seed sources for his own planting sites. The release of such a plan would make available a considerable research background of experimental technique and design, reference reading, and experience, at a saving to many planters. Simultaneous use of the same plan by a number of planters would permit fairly direct comparison of their results. Any such comparison would be a valuable supplement to the proposed cooperative study.

Early solution of the problem of geographic strains of southern pines is urgently needed to insure best results in hybridization and tree selection, and maximum returns from routine planting. Any contribution you can make, either by cooperating in the comprehensive study or through independent tests, will help.

Paper for Conference on Forest Genetics Research in Southern Pines

January 9 and 10, 1951

OPPORTUNITIES FOR SELECTING SUPERIOR PHENOTYPES

*E. G. Wiesehuegel

Phenotypes exemplify the variations which occur within wild plants. According to Forest Terminology,[8] a phenotype is defined as "the organism as exemplified by its expressed characteristics as contrasted to its genetic construction (genotype). It is the plant as we see it." This natural selection of forest trees, which is constantly going on, may ultimately lead to pure crops of a definite local race, or physiological variety. When this occurs it is usually due to natural cross-breeding and occasional inbreeding of phenotypes having superior characteristics for the particular site in question and thus may lead to the development of a genotype which may reproduce itself. In the field of horticulture, selections which are vegetatively propagated form the backlog of the business.

If a genetics project with the southern pines is to be undertaken seriously, one of the first objectives should be the recognition of and location of superior phenotypes. Once found, the trees having the characteristics desired may be multiplied vegetatively and used for breeding purposes in order to develop genotypes combining various desirable characteristics which may be passed on to their progeny in a high percentage of cases. Thus it is important that we realize that before much can be done in the way of developing true hybrid strains, it will be necessary to collect these phenotypes,

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multiply them, and put them in orchards which can be used as a source of breeding material for artificial crossing, a place where natural crosses may be developed, a place where these superior strains may be tested as to their adaptability to the locality and for use as seed orchards.

Although the characters marking phenotypes may be visible to the naked eye, many phenotypes may be characterized by features which are microscopic or hidden. Some of the more easily recognized characteristics would be crown form, bole form, character of branching, size or coarseness of branches and other branching habits, seed production, and disease resistance. Other characters which may be superior in some phenotypes that are not so obvious would be variations in wood quality, such as fiber length, specific gravity, wood composition, figured or unusual grain, heartwood, durability, and many others. For example, variations in the gum yield of southern pines have already been studied and selections have been made which will produce higher yields, but very little development or research work has been done on other variations which occur in the southern pines.

As a beginning, those interested should recognize that phenotypes with either especially desirable or undesirable characteristics may have developed through generations of adaptation to the environment, and that no two individual trees are alike among the southern pines. Among the infinite variations which occur, some are much better than others with regard to specific characteristics, and these should be sought out and used in a breeding program if the optimum productivity of the southern pine forest region is eventually to be achieved.

Sometimes deviations from the normal type are readily observed, but more often they are discovered only through positive observations taken in a scientific manner. This is particularly true in the case of the pines where differences due to spacing, soil, fire, and other environmental factors may have caused variations difficult to separate from those caused by natural selection through several generations. The true value of such trees when selected for use as parents can only be determined by the performance of the offspring, and considerable investigative work is necessary in order to ascertain that the characteristic supposedly discovered in a certain phenotype may be of real value for breeding purposes. Some of the more obvious examples of phenotypes may be found more readily in red cedar than in pine, and these are mentioned because they are so commonly observed and have become recognized varieties in horticulture. The columnar cedar, the global cedar, the pyramidal and procumbent types are commonly seen. All of these include variations, from fine, erect branches to coarse branches and drooping branches, which may have significance in developing superior trees. The effect of such habits of growth may have a direct relationship to wood production, both in quantity and quality. It would seem obvious that finely branched specimens would have smaller knots and a higher quality of lumber than those coarsely branched. For example, an erect, finely branched Virginia pine would produce lumber with smaller knots and of higher grade than one with coarse branches which prune with difficulty, either naturally or artificially. An increase in #1 common and better produced from Virginia pine would be a real contribution to poor site productivity.

In considering the theoretical ability of trees to produce wood, for example, suppose we might study the effect of crown form on wood production. The

efficiency of trees in achieving a high rate of growth, other conditions being equal, may be due primarily to the amount of solar radiation received by the chlorophyll. These rays are used by the chlorophyll in the manufacture of food and wood and thus one might deduce that the crown forms which intercept the greatest amount or perhaps some other given amount of sunlight will be most efficient in wood production. Thus the propagation of such phenotypes in our future forests might prove exceedingly valuable in improving growth rates.

The possibilities of improving wood quality, such as mentioned in connection with the finely branched Virginia pine, may have even greater possibilities. Or, if figured wood from walnut, maple, or birch could be reproduced, this would be of great importance. These examples are not beyond the realm of possibility and afford an opportunity to the industry to greatly increase its returns in the long run.

In the past, however, much of the effort in the woods has been in the opposite direction. Practically all of the grade yield studies that have been made show that the trees now being sawed are largely of low grade and relatively large (18" +) size in the hardwoods. Small trees are cut if they are of better grade; the low grade small trees are left. The trees commonly left are of poor form, low disease resistance and low quality. The superior individuals have been removed. The progeny from such trees cannot be expected to regenerate the forest with superior individuals which will produce the high grade lumber the market has been accustomed to in the past. On the brighter side, more and more trees are being marked for cutting by foresters and there is at least some conscious selection of the poor trees for harvesting

and of the better trees to be left for future growth and for regeneration of the stand. This type of selection has significant genetic aspects and, in the long run, will provide considerable improvement in the quality and growth characteristics of our forests. Thus the possibilities for tree and stand improvement range from the selection of phenotypes representing the better individuals in connection with marking operations to their conscious selection and multiplication for breeding purposes. Some of the more significant examples of variations which should be sought will now be discussed.

The following discussion is arranged in order of the particular tree characteristic representative of the phenotype concerned and will largely cover some of those noted by Dorman in his paper, "Genetics of Southern Pine."[3] Another presentation which might have been used would be to discuss the causative agents which resulted in the determination of phenotypes, such as frost conditions, soils, maximum and minimum temperatures, closeness of canopy, wind, burning, pasturing, snow, etc. This is the presentation followed in Büsgen and Münch, "Structure and Life of Forest Trees."[2]

Crown Form

This has already been discussed as an example in connection with the red cedar. However, phenotypes which develop a true columnar form, probably resulting from trees being subjected to continuous competition in a densely growing forest, should be sought. As pointed out previously, trees of such form usually have smaller limbs and make use of more solar radiation than other forms of crown. They are generally also more resistant to snow and ice damage but when opened up may be more prone to windthrow. These considerations are all important to the southern pines in some sections of the South. If, over

a long period, conditions become so unfavorable that a close canopy cannot be maintained, upright growth of trees is discouraged and they are then generally disposed toward a broader and lower growth, which makes less effective use of the site. In Germany pine from the southwest part of the country is regularly damaged or crushed by snow if transplanted into the mountains. On the other hand, the upland pine with its relatively slender crown and pliant branches, withstands regularly the heaviest loading of snow.2/ This difference in form is also striking in the case of the Rocky Mountain and Pacific Coast varieties of Douglas fir. Very little seems to be known concerning the respective efficiency of various crown forms found in southern pine but the subject would seem to be a promising field for investigation.

Stem Form

One of the best known examples of the use of phenotypes with good stem form is the use of the shipmast locust as compared to the common locust, with which you are familiar. In the Tennessee Valley area we have tested numerous clones of the shipmast locust and have found the Kimberley locust from Long Island and the Higbee locust from southern Indiana to be the best combination of straight stem and rate of growth for Tennessee Valley conditions, but growth is slower than common locust. Selections from these clones for durability have not yet been made.

To a considerable extent, the same differences in stem form are quite obvious in Virginia pine in various parts of its range and I have observed some similar differences in loblolly pine, especially in Kentucky. Usually the most vigorous tree in the seedling and sapling stage is the one inclined to develop poor stem form. This was found true with slash pine collected from

six sources and planted in four locations in South Africa. The trees which showed the poorest form throughout were the most vigorous growing of the imported stocks which, by the way, came from north Florida. Again, in the case of loblolly pine, the Florida and Louisiana stock was significantly superior to most of the others in rate of growth and was also inferior in form.[7] Pinus rigida, pitch pine, also varies considerably in stem form from locality to locality and the straight stemmed selections might be worthy of propagation. That stem form is inherited has been well proven and tested in Switzerland, Germany and Sweden.[4]

Growth Rate

Selections for optimum growth rate and volume per acre have good possibilities in the southern pines. Some of the most significant studies have been made in South Africa where trees grown from slash pine seed collected in British Honduras and from Georgia were grown on comparable sites. The plot of British Honduras origin grew twice as fast as that of the United States origin. The rate of growth for all of the loblolly and slash pines tested there varied greatly with the latitude, increasing quite regularly as the plantations were located further south. This gives some indication that there may be different clines represented in this species at various latitudes.[7] Last year some tests of seedlings of loblolly pine from several locations in the South were started by several agencies cooperating in the project, using trees furnished by TVA from known seed sources. This is just a beginning in this field, but is indicative of the kind of cooperation which may be necessary in order to successfully pursue projects of this character.

Wood Quality

Variations in fiber length are known to exist within trees and are known to vary somewhat from tree to tree in a given species. This is also true of specific gravity. The evidence, however, is so far inconclusive and warrants further study, particularly because of its importance to the pulp and paper industry and its relationship to paper quality.

Disease and Drouth Resistance

Wakeley,[10/] in connection with seed source studies, found considerable variation in the susceptibility of loblolly pine to infection by cronartium. Trees of local stock from Louisiana had only a 6.5 per cent infection, whereas Georgia stock had 32.1 per cent trunk infections. In the case of brown spot disease in longleaf pine, disease free seedlings may be observed growing beside those with a high degree of infection. It was found that the resistant seedlings exuded a higher percentage of resin than those which were susceptible to infection. Some experiments with white pine being tested for resistance to blister rust are showing significant and encouraging results. These tree selections were made because they showed no blister rust after fifteen to twenty years natural exposure to infected *Ribes*.[6/] In the Tennessee Valley we have had some experience in making selections of hybrid poplar clones for resistance to the canker disease. Out of 35 clones tested, only one, No. OP 32, was found to be sufficiently resistant to cankering.[1/] Thus it would seem that selections of southern pines for resistance to some of the more common diseases, such as blister rust, needle cast, brown spot disease, canker and little leaf disease, might prove of benefit in the development of resistant strains.

Heat Requirements and Frost Sensitivity

The Woody Plant Seed Manual[9] recommends that seeds used in commercial seedling production be collected not more than 150 miles from the point where they are to be planted. This is largely in recognition of the fact that local races have developed which transmit to their progeny a very marked sensitivity to temperature and perhaps soil conditions. I found long ago that yellow poplar grown from seed collected in South Carolina froze to the ground in the nursery in Ohio. Such observations on first year growth are readily made in tree nurseries. Dorman[3] points out that one year old slash pine from Cuban and British Honduras seed, which was sown in Texas in 1929, was much less frost resistant than stock from Florida seed. Lots of shortleaf pine from several origins grown in a Louisiana nursery showed great differences. Trees grown from Pennsylvania seed ceased growth much earlier and grew less than those grown from seed collected in Texas. (Of course this would be expected from Texas seed.) Loblolly pine trees, probably from Georgia seed, were grown in southern Ohio for many years, until the cold winter of 1930, when temperatures reached -26° F., killed the stands completely, after the trees had attained diameters of 9-10 inches. Thus, extreme care will need to be exercised in selecting phenotypes for propagation for a particular characteristic to give adequate consideration to corollary characters or the whole purpose may be upset by some character which makes the tree unadaptable to the situation for which its use is proposed.

Seedling and Flowering Habits

These vary greatly with changes in latitude and vary characteristically even within relatively small areas and by individuals. Thus, for example, tests of the progeny of good seed producers are necessary to determine whether or not

this is an inherent trait or simply a phenotypic condition. For instance, Pomeroy[5] found in 1949 that over a nine year period the most prolific trees matured cones each year, whereas seed crops generally occurred only at intervals up to five years. Some individual pine trees characteristically have few cones, while others fruit heavily. This is of particular importance if clones are to be propagated from superior phenotypes for the purpose of developing seed orchards. Unless we select phenotypes which will produce abundant crops of seed the testing of these may be considerably delayed and their usefulness as seed sources materially reduced. This may be tied in directly with the flowering habits of the trees and these should be studied for each of the species of southern pines as a part of the proposed program.

Research Program Possibilities

A program of selection would inevitably extend over a very long period of time and therefore must be well organized and assured of permanent staffing and financing. This is a subject which should merit a great deal of thought and careful consideration by this group. Technically, the field breaks down about as follows:

1. Propagation of selections
    - A. By grafting
        - a. Techniques
        - b. Influence of stock on scion (compatibility)
    - B. By cuttings
2. Development of arboretums geographically and climatically distributed for growing, testing and holding selected phenotypes. These arboretums will provide locations at which the character and form

of trees obtained by vegetative propagation may be studied.

3. Study and select desirable phenotypes throughout the range of each species of southern pine. Those having desirable characteristics would be tested as provided above. In this connection, a uniform system for identifying southern pine phenotypes and clones should be developed. Some material has already been published in this field and other studies are now under way. For example, TVA is contemplating making selections from the millions of trees now produced in its nurseries from various seed sources. It is planned to set out in orchards those one-year seedlings which are 50% or more taller than their immediate neighbors. These individuals will then be available later for testing, seed collection, and hybridization studies.

4. Locate stands representative of the superior pine phenotypes for each species, these stands to be used for seed orchards, from which seed can be obtained which will produce a higher percentage of superior individuals than that now normally obtained in commercial practice.

5. Study the phenology of the southern pines, including flowering habits, seeding habits, seasonal growth, and other characters which would affect the usefulness of individuals in hybridization and other breeding studies.

6. There should also be considered the establishment of a central agency to coordinate studies and projects and develop standardized techniques. This agency could act as a central source for information and would seek support for breeding investigations from private agencies. It

would be the central core around which the genetic development of southern pines could take place and should provide for the cooperation of all agencies, both public and private. Without some organization of this type, duplication of effort is bound to occur and the cost of individual projects would be greater than if coordination could be achieved. Furthermore, the necessary geographic and climatic distribution of testing grounds makes it almost essential that the development of such a coordinating body be considered.

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BETTER SEED FOR FOREST PLANTING IN THE SOUTH FROM NATURAL STANDS

(Floyd M. Cossitt)

I want to talk about obtaining seed from natural stands and superior individuals among them, which, after all, must be relied upon as the basis for the planting programs for a long, long time. No one has any expectation that hybrids will replace natural seed; rather, these should be considered as an addition. This in no way minimizes the importance of securing the best possible seed from such genetically superior plant material which may be found among the now existant trees.

Phil Wakeley has already given you a clear, concise picture of the importamce of the geographic strains which have been found. Obviously, everyone should be governed by these findings in the selection of seed for the huge planting program now under way. No one realizes more keenly than I of the need for more data.

From a practical standpoint, it is not always possible to obtain seed from the desired geographic strains. Seed crops are extremely variable, ranging from complete failures to bumper crops. A long-range seed procurement with proper cold storage facilities go a long way in maintaining adequate seed supplies. Unforeseen contingencies such as changes in field planting programs, extraordinarily long periods between seed crops, nursery catastrophes requiring re-sowing a crop, frequently create seed shortages, which, in turn, result in an unbalanced nursery sowing schedule. With our limited knowledge of the outer limits to which seedlings can be moved from their natural locale, it is inevitable that some will be moved too far for best results. Those responsible for planting programs are always under pressure to supply seedlings for all and unless due consideration is given to seed provinces there is grave danger of making serious errors. The ideal would be to have a never failing supply of seed wherever and whenever we want it. Such, of course, is only wishful thinking.

There is, however, increasing evidence that we can, through proper management and possibly fertilization, increase the seed yield in a managed stand. Given ample room, trees will produce larger quantities of seed three years after release regardless of the general level of seed production for surrounding stands. Heavy crops have been observed in the fourth and fifth year after release. Just how long the seed crops will remain at a high level remains to be determined. A series of planned released cuttings would be of material benefit to those responsible for seed procurement.

Let us review briefly the standards which may be observed in releasing a stand for seed production. These are:

1. Leave the best well formed trees with ample space around each seed tree.

2. Remove all trees which are not good seed producers.

3. Remove all associated species which would interfere with economical collection.

A vigorous young stand, well located on level or gently rolling topography, is preferred to older stands on rough terrain. I feel that cone collection costs can be reduced by the use of mobile extension ladders where the topography is favorable and the quantity of cones great enough.

Experiments are now under way using fertilizer to stimulate seed production. There is some evidence that trees will produce more seed, particularly in "off years" - that is, in years of generally limited seed crops. Furthermore, the quality is better; seed is larger and the yield per bushel of cones is greater. The direct ratio of large plump seed to the vigor and rate of growth of the resulting seedling is a well known fact. I would like to see the results on seed production of a released and fertilized stand.

It is not expected that released trees or fertilized stands (if this proves to be an effective measure) can furnish all of the seed needed for a large sowing schedule. The bulk of the seed must come from other areas in years of bumper seed crop. Their greatest service would be in "off years" when seed may be badly needed for a given locality. In fact, the cost of treatment and maintenance would be returned in a very short time by reduced collection costs, particularly when nurserymen must pay from $4 to $10 per pound for seed from any source.

We have been considering the collection of open pollinated seed from trees of good form. In other words, a "run-of-the-woods" source. Now let us turn our attention to laying the groundwork for improving the quality of such seed.

In natural stands we find at rare intervals a beautiful specimen with outstanding form, a fast rate of growth, free of disease and insects - altogether an ideal tree. The question now arises - Is this tree superior because of environment or is it truly genetically better than its neighbors? Is it superior enough to justify being considered as a distinct improvement over its associates? If it is strictly environmental, then there would not be any advantage to using it as the basis for superior progeny.

In testing a tree for superiority a number of measurements are made on which to judge its worth. I shall not recite all of them here but essentially it is to determine if it is actually a better tree. Such measurements include age over height compared to at least four dominates in the same stand. The rate of growth must be superior to all of its associates, its form and height well above that of the dominates. If the candidate passes, then we must know: Is its superiority due to environment? If it is due to this, then we have no further use for it.

Obviously, we cannot pick up the tree and move it to prove the point, but we can test it genetically in a new location by grafting and growing an offshoot in a designated seed orchard. Grafting and rooted cuttings are proven methods of perpetuating selected plant material and permits the testing of identical material in several localities. By a series of tests a tree can be established as an elite specimen suitable as a base for both open and controlled pollination within the species, hybridization as desired, and the source of pollen for crosses in other locations.

I would like to say a word about the lay-out of the seed orchard. Incidentally, a plantation composed of candidates for the elite classification is, to me, truly a seed orchard. The lay-out of the seed orchard should be such as to permit the rogueing of trees which do not pass the environmental test in its new location. There are going to be a number of these regardless of how ruthless the candidates are culled in their original location.

Another method of securing superior progeny would be through controlled pollination. When two superior trees have been elected to the elite classification through the seed orchard method, it is entirely practical to control the parentage for a limited amount of seed.

Plantations from such seed could then be established for further testing and if they proved to be superior, they could be used as a source of open pollinated seed. Again, rogueing of poor and fair trees would be an essential step as soon as they can be determined. Here, at least, one of the parents would be of proven origin. There is some evidence that progeny from one superior parent yield a higher percentage of good trees than those from unknown parentage. This may not apply to all southern pines, but apprently slash pine can be improved in this manner.

It is natural to ask - why not extend this practice to all southern pine species? If it is true for slash pine, wouldn't it hold good for other pine in this section? In this way, progeny would be assured of at least one good parent.

The theory must be tested before it can be accepted and, at the present time, there is no agreement among geneticists on this point. It is argued, and rightly so, that genetic superiority must be proved before it can be assigned. Form, good growth rate, and other desirable attributes, due to environment, are not transmitted to their progeny. Testing of all superior individuals is an important point in the study of genetics. In the meantime, we can and should include the poorer trees, since there is a wide variation in plant material. We will, in this way, be assured of better-than-average seed.

In summary, I would like to point out that natural regeneration obtained from open pollinated seed is going to be a potent factor in forestry for a long time to come. It is reasonable to think that if superior strains are developed these could be planted even in well stocked areas and reserved as seed trees for several rotations.

I want to emphasize that the development of better strains of trees for seed production is an important phase of the tree improvement program. It should be parallel to the development of suitable hybrids. Relatively small gains made by judicious manipulation of genetically superior individuals has the potentiality of increasing timber growth over a large acreage. Returns may be as great or greater than increasing the yield through the use of hybrids on a more restricted acreage. Both phases have their place in our consideration of the problem.

HYBRIDIZATION IN IMPROVING SOUTHERN PINE

Keith W. Dorman

We have seen in the previous papers in this series the possibilities for making improvement in tree species by selecting better strains, better individuals, more disease-resistant types, and producing seed of these on a commercial scale.[1] By so doing, we can reproduce in quantity the superior individuals now existing. If we make a further step and combine selection with still another operation--namely, the hybridization or crossing of superior trees--the chances are good that we can produce even better pines than now exist in nature. These will be made-to-order pines, which we can't describe as yet because we've never seen them.

A good start in hybridizing has already been made. Sensational results have been obtained in other regions and countries. Some hybrids grow two to three times as fast as the parents, and there is one of these hybrids suitable for planting in the West, the Lake States Region, and the Northeast. The important job now in tree selection combined with breeding is to produce a highly vigorous, disease-resistant, high-quality tree for planting in the South. The possibilities are excellent because we have nine species with a wide variety of traits in this general region. Crosses should be made between these species as well as with species from other regions and countries

Methods and Purposes of Controlled Breeding

In forestry, controlled breeding has many possibilities for use in both intensive and extensive methods. Intensive methods performed by hand are usually on a rather small scale and involve crosses between flowers on the same tree, between trees of the same species, or between different specie Extensive methods are conducted on a much larger scale, as in seed orchards where isolated groups are planted in such a manner that cross pollination is under natural conditions. Control is obtained by composing the groups with selected material.

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[1] Paper presented at Forest Genetics Conference, Atlanta, Ga., January 9 and 10, 1951.

The intensive methods are suitable for experimental work and for producing material for establishing seed orchards. Both methods are at present included in forest tree-improvement programs in Australia, South Africa, Sweden, Denmark, Great Britain, Canada, and the Northern and Western United States.

We have seen that there are a number of ways of making controlled pollinations, and likewise there are a number of results to be gained. The methods to be used are governed by the objective desired, just as in other silvicultural or forest management practices. Some of the advantages of controlled breeding are as follows:

1. It gives a very high control of quality in the offspring because both parents are known.
2. It provides a method, when combined with selection, for producing a much wider variety of genic combinations than is obtainable in natural populations, especially when species or races are crossed.
3. It may produce stock with hybrid vigor.

These items have immediate and practical value in the improvement of local tree species. We could start tomorrow and might have valuable leads within three or four years. There are two more advantages of controlled breeding that are of interest to long-range programs or basic studies of forest genetics. These are:

1. It gives, over a period of time, pure lines of very uniform material in self-pollinated plants.
2. It provides a method for studying inherent traits.

All of these points will be discussed in detail later on when we cover the southern pines in more detail.

History of Tree Breeding

It will help us understand some of the methods of controlled breeding and organize a program of work if we review briefly the history of pine and hardwood tree breeding. The oldest known attempt at deliberate crossing of forest trees is reported by Klotzsch, who in 1845 amongst other species produced *Pinus sylvestris* x *nigricans*, *Alnus glutinosa* x *incana*, and *Ulmus campestris* x *effusa*. Thus pine, alder, and elm figured in this first successful effort to breed forest trees. This work did not attract much attention, and neither did Luther Burbank's hybrids of walnuts produced in 1877 to 1887, although they too displayed very luxuriant growth. In 1909, N. Sylven began experiments with self-pollination and the progeny of wind pollination of Norway spruce as a basis for investigations into the inheritance of various branch types in that species. The hybrid between Japanese and European larches, described by Henry and Flood in 1919, attracted considerabl attention among foresters. Crosses between two species of fir were made in Denmark in 1924. In 1932, A. Dengler published results of his work with Scots pine.

Since 1925, when the Institute of Forest Genetics was established in California, many crosses have been made with pine in the west. The Northeastern Forest Experiment Station has been working with hardwoods in the Northeast. A program involving more than a dozen agencies, some of which are in Canada, for breeding white pine for resistance to blister rust has been organized in recent years. The program of the Tennessee Valley Authority has attracted wide interest. The breeding program for poplars and disease-resistant chestnuts is quite well known.

The first crosses with southern pines were made in 1929 by Mr. Wakeley at the Southern Forest Experiment Station. The Institute of Genetics has a 17-year-old tree of a longleaf-slash pine cross and one of a shortleaf-slash pine cross. In more recent years crosses have been made betwen the four major species of southern pines, but none between selected trees of each species except on the new Callaway project in Georgia last spring. Very few crosses have been made with the minor species, such as sand, pond, Virginia, pitch, and spruce pines.

At Lake City, Florida, in 1943, slash pine trees selected for gum yielding ability were crossed. Progeny are now five years old. They were planted with seedlings from controlled pollinations between high-yielding and average trees and seedlings from wind-pollinated average-yielding and high-yielding trees. A very few crosses were made between slash and longleaf pine, but these were generally unsuccessful.

In 1942, Australian foresters inbred selected slash and loblolly pine. These were plus trees that, on the basis of test results, have proven to be "elit e" trees. Results of this work are very significant, and will be discussed in more detail later on.

In 1950, a project in tree improvement was started at Hamilton, Ga., near Columbus, under the Ida Cason Callaway Foundation in cooperation with the Southeastern Forest Experiment Station. The program includes testing of superior individuals, strains, and work in hybridization.

Results of Pine Breeding

What have we learned from controlled breeding with pine? We have learned how to do the job. This has meant solution of problems in pollen collection, extraction, and storage; also, solution of problems in bagging and pollinating the flowers. We have learned more about blooming habits. Improvements can be made, but we do have usable techniques right now. The publication "Methods Used to Control Pollination of Pines in the Sierra Nevada of California," U. S. Department of Agriculture Circular 792, outlines controlled breeding techniques.

Another thing we have learned is that some crosses give very vigorous offspring. This great vigor may be so high that in a very few years the hybrids are two to three times as large as either parent. Crosses between similar species, but from widely separated regions, have often given hybrid vigor. High vigor has been found in crosses between Jeffery and Coulter pine, Ponderosa and Apache pine, lodgepole and jack pine, eastern white pine and western white pine, and between western white pine and a white pine from India. We have found high vigor in some cases in offspring between trees of the same species, but different geographic strains. In pine breeding work at the Institute of Forest Genetics, about one species cross in seven has given increased vigor in the offspring. Increased vigor has not been found in crosses made to date with southern pines. Most of the offspring are intermediate in regard to their parents.

We have found crossing very easy with some species of pine and very difficult with others. A summary of the work up to about five years ago showed that only those species with the same number of needles crossed readily.

There is some information on results of inbreeding. Pines are generally cross pollinated, as indicated by the difference in blooming period between the male and female flowers which we know occurs in some species. Inbred Scots pine, spruce in Europe, and Jeffery pine in California gave offspring with much lower vigor than wind-pollinated seed from the same mother tree. In Australia, inbred slash pine elite trees gave a larger proportion of top-grade offspring than wind-pollinated seed from the same tree or wind-pollinated seed from average trees in the stand. All the progeny were classified into five vigor form classes. Fifteen percent of the seedlings from the three inbred trees were in the best class. None of the seedlings from open-pollinated seed of average crop trees was in this class. The 15 percent may be a large enough group to form the final stand of trees. A total of 45 percent of the inbred stock was in the two top classes as compared with one percent of the open-pollinated stock. Putting these figures another way, from routine seed collection they got 160 top quality stems, from open-pollinated seed of superior trees 350, and from inbred seed of superior trees they got 570 good stems per acre. The inbred stock was definitely superior in form and vigor to the average material. In loblolly pine, the progeny were no better than those from wind-pollinated seed from the same superior mother tree. They gave better trees than wind-pollinated seed from average crop trees, inasmuch as there were 13 percent as compared with 3 percent in the two best vigor form classes. Here is a concrete example of the value of selection and controlled breeding of southern pine. However, geneticists don't know what would have happened if they had crossed two elite trees instead of inbreeding each one. All this adds up to the fact that we don't know the full story about inbreeding. With southern pines we have data that is encouraging from one study with slash and loblolly pine. We don't know about the other species.

Before we leave the summary of what has been learned about breeding, we might consider some developments in an allied field. This has to do with chromosomal changes through mutations under natural conditions, or induced changes such as by special radiation or shock treatments. There is always a chance of sudden changes in genetic characteristics that may improve vigor or quality, and we should be on the lookout for them. So far, they have been of more interest in the hardwoods, such as the giant aspen in Sweden that has multiple sets of chromosomes. In the willows the basic chromosome number appears to be 38, but there is a parallel series of 44 chromosome forms, and sometimes representatives of both series appear in the same species In one species, *S. triandra*, some individuals have 38 chromosomes while others have 44 or 88. In another species, *S. Myrsinites*, some individuals have 38 chromosomes while others have 190, or five sets of chromosomes. There is a mutation in shortleaf pine in the arboretum at the Institute of Genetics. It is a dwarf form and of little value. Sometimes these oddities are of value for special purposes. The Southeastern Station and other groups in the South are cooperating with Harvard University in testing seed that has been exposed to atomic radiation. The seed will not be planted until this spring, so there are no developments as yet. It may be advisable to pursue this type of work if it is warranted by current research with many crop plants.

Quite understandably, we have heard much of the striking mutations, especially those that have given rise to products of higher commercial value. Some geneticists feel that in the long run the small mutations that may not be so striking, but which occur in large numbers, are of much greater value in plant-improvement programs. These small mutations, as well as the large ones, may be an improvement or they may be in a downhill direction. In fact, these undesirable mutations are in general far more frequent than those which increase or intensify an organ or character.

Some Projects in Tree Breeding

We have discussed some of the methods of tree breeding, the objectives, and some of the things we have learned. Now let us consider some of the things that can be done. Most of the following suggestions are rather broad projects. These can be broken down into small units or studies, and many can be done separately for each species.

1. Make crosses between all southern pines. This is a quick once-over to see if we can get any measure of hybrid vigor with local species. Later on, crosses can be made between selected, disease-resistant trees of the best geographic strain to make use of the accumulated good qualities.

2. Determine effect of inbreeding for all species of southern pines. This is a rather important field of work because of its practical application to design of seed orchards. If inbreeding is not harmful, it will be possible to plant orchards of few clones or only one clone to produce good seed. If it is harmful, we will have to plant several. This has been an important factor in Sweden, where they have a very few really elite trees. Also, we can produce a fairly large amount of seed for establishing seed orchards by inbreeding just one best tree, assuming we'll have a variety of good trees to pick from.

3. Breed for special purposes. This is aimed breeding. We can breed for more height in southern pines. Perhaps this can be done by crossing with certain western species. In the naval stores region, we want a tree that produces a lot of oleoresin as well as one that is vigorous and has other desirable qualities. We will want to breed for disease resistance by crossing certain individuals, strains, or species. Increasing drought resistance by crossing with certain western and Mexican species may be very important. Breeding for improved form such as narrow crowns, small branches, and better

natural pruning is desirable. Also, we may want to create or isolate types with uniform quality of wood as well as extremely light wood for newsprint pulp, or heavy wood for kraft pulp or special uses.

4. Methods of stimulating flowering in young trees. This is an important factor, and, if possible, may speed up both the long-range studies and production of quality seed in young seed orchards. A study of this type could begin with isolation of factors controlling flowering as well as application of methods for artificially stimulating it.

5. Improved tree breeding equipment and methods. For example, an improved pollinating bag that could be quickly and easily placed would speed up the field work. This is probably the most time-consuming part of the entire cross-pollinating operation. Present methods require stripping needles from stem, wrapping with cotton, removing seal from bag, placing bag over twig, and tying with string. Perhaps a bag with built-in cotton pad and elastic could be designed that would be much simpler to use. Some of the Swedish equipment for tree climbing should be tested.

6. Design of progeny tests. In this field there is need for some study that could probably be handled best in cooperation with statisticians. It is important, and may help speed up the work. We don't know whether we need ten or ten hundred trees in tests of various kinds for various objectives. In this same field we may want to use vegetatively propagated stock for accurate comparisons. This, of course, would require that rooting or grafting techniques be developed for producing stock of this kind.

7. Set up a catalogue of breeding stock. This would include individuals, strains, and plantations of introduced species.

8. Study of mutations and polyploidy. This field is of limited importance as long as we put the emphasis on pine breeding, but it may be very important in the work with hardwood species. We want to keep the

door open to material of this kind or techniques that may be developed.

Conclusions

This and preceding papers have given a bird's-eye view of the field of forest tree improvement. The job is now to organize the entire field so that we can make use of every means for a step ahead. The combined effect of good individuals, good strains, and vigorous hybrids may be very striking. There are going to be forests in the South for a very long time, and improvements in quality are just as much our responsibility as are other phases of forestry. Some measures to improve quality can be applied right now in our seed collection work. Others can be made in the near future as current studies are completed. Still more improvement will be possible as new work is finished. A broad program of genetic research should produce new and usable information each year, just as our programs in silviculture and forest management research do.

THE DISEASE PROBLEM IN RELATION TO TREE IMPROVEMENT[1]

By Ralph M. Lindgren[2]

If the work done on other crop plants is any indication, adequate resistance to disease will be one of the most important phases of a forest-tree improvement program. I don't think any of you need to be convinced of this, but if such history with other plants isn't enough, we have a tree case in our own territory which is one of the world's most striking examples of the need for properly recognizing diseases. This example is the chestnut blight disease, which in about 40 years resulted in the practical extinction of an entire species. The blight alone already has resulted in a fairly large amount of work of the type that we are discussing. In fact, such work represents some of the earliest on forest-tree genetics in the United States.

Before considering the possibilities and difficulties in planned studies on increasing resistance, let's spend a few moments on the general disease situation in virgin stands and in stands of today. Theoretically, virgin or undisturbed stands were largely a case of the survival of the fittest so that natural selection for disease resistance probably was a continuing operation. Since the chances of introduced diseases were remote and since native diseases seldom cause widespread devastation in natural stands, epidemic conditions must have been rare. Furthermore, stands undoubtedly were often dense so that many trees could be lost without serious effect on final stocking. Similar tree losses today would be much more damaging, particularly in plantations with a limited number of trees and from which intermediate as well as final products are expected.

The situation now on disease liability depends on the practices that have been followed in cutting and reproducing the stands. For instance, the widespread early practice of "high grading" has worked to decrease rather than build up the resistance of the new forest. This practice still continues to some extent, particularly in the harvesting of hardwood stands. Even under the best management practice today, however, it is difficult to judge whether the chances for disease escape are better or poorer than under undisturbed natural conditions. To the extent that diseased trees are being eliminated early, mixtures are encouraged where pure stands existed before, and the best sites are favored for species - we are tending to improve the disease picture. On the other hand, disease liability tends to be increased to the extent that mixed stands are replaced by pure ones, trees are grown outside of their natural range, and plantations are favored over natural regeneration, particularly if the seed source is from some distant place.

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[2] U. S. Division of Forest Pathology, in cooperation with Southern Forest Experiment Station, New Orleans, Louisiana.

It is very doubtful whether natural selection for disease resistance is now operating as effectively as under an undisturbed stand condition. One reason for this is that the use of direct methods of disease control often permits the survival of susceptible as well as resistant individuals. One case in point is longleaf in areas where brown spot is heavy. In the absence of prescribed burning or fungicidal sprays, the plants making earliest height growth are likely to be the most resistant ones. These tend to comprise a larger proportion of the final stand than when brown spot control measures are employed. Finally, one cannot overlook the present real threat of introducing new diseases from other countries, plus the fact that abused and depleted sites often confront the tree with a changed natural environment that often may increase the disease hazard.

In a tree improvement-program, the disease more than any other phase could eventually find us guilty of having looked through rose-colored glasses. It may seem from the following that I am substituting opaque ones instead, which is not the case, but we must be realistic and recognize some of the possible obstacles in our path. Among the foremost is that diseases of trees are largely caused by fungi, although there is a good possibility that the little-known virus agents will become increasingly important. If so, the problem will only become more complicated. Anyway, fungi, being plants, hybridize as we now talk of changing trees, and furthermore, mutations are not uncommon for many of them. Generations in their case are a matter of hours and days, not years or decades. This means that new varieties or biologic forms might arise that would make last year's resistant tree a susceptible one today. Among annual plants, the stem rust of wheat is an outstanding example of a disease that continues to produce new forms that periodically relegate resistant wheats into the susceptible class. Among trees, there is recent suspicion that the resistant Buisman elm may be susceptible to a new form of the Dutch elm disease fungus. Variability within species for a number of other fungi, including those causing heart rots and mimosa wilt, is known to occur. Fortunately, the present evidence is that such tree rusts as those causing white pine blister rust and fusiform canker diseases have not given rise to new forms differing in parasitism. However, it would be foolish to ignore the threat, considering the short time diseases have been observed ahd the long time needed for rotations or the development of superior individuals.

Another possible difficulty is that stock bred for resistance against certain diseases may prove susceptible to diseases normally harmless to the tree being replaced. This has been the case with some of the fast-growing poplars, and Asiatic and hybrid chestnuts. It has been strikingly true of the hybrid London plane, which showed resistance against sycamore anthracnose but has succumbed in large numbers to the canker stain disease. With the hybrid poplars and London plane, susceptibility to disease and hybrid vigor were associated. One advantage that trees have had over annual crop plants is that they are much more heterozygous. The closer genetic uniformity is reached in large populations the greater is the risk of heavy losses from epidemic diseases. Hazards would be very high, for instance, in extensive plantings of clonal propagated stock since this would be a great refinement of pure stands of species. Such clonal varieties as Lombardy poplar, Norway poplar, and London plane already have been seriously troubled by diseases that apparently caused minor damage on the closely related native trees. As Hartley and Boyce have warned, unless mixtures of superior clones are at least used, the disease status in planted forests could easily approach that already apparent in our present-day orchards.

What has been said is not intended in any way as an argument for placing our entire reliance in unselected planting stock. Such diseases as the chestnut blight, white pine blister rust, and littleleaf are good examples of why we want and need the advantages that superior strains would offer. A brief history of work in this direction, for trees other than the southern pines, is that in 1909 the chestnut blight provided the first strong incentive in this country to select and breed resistant forest-trees. In 1924, poplar improvement was started, with diseases partly in mind. About 1935, research began for elms resistant to the Dutch elm disease and to phloem necrosis, a destructive virus disease. At about the same time, the work of selecting white pines resistant to the blister rust was undertaken. In 1939, Hepting and his coworkers embarked on the selection of mimosa strains resistant to the wilt disease. Among the encouraging results so far are a number of selections that have continued to show high resistance against mimosa wilt and phloem necrosis. In both cases, vegetative propagation has been found possible through the rooting of stem and root or leaf bud cuttings. A hybrid between a Chinese and the American chestnut has indicated promise for forest plantings but is in an early stage of testing. Resistant selections have been obtained against the white pine blister rust, and both rooted cuttings and grafting have been employed with some success in propagating such strains.

As to our southern pines, each of the important species would be considered a better tree in some localities if diseases were not present. For longleaf, brown spot is often troublesome in delaying early height growth and even causing mortality. In the case of slash pine, the fusiform rust canker disease proves a limiting factor for this species in local areas, and also causes losses of varying degrees in widespread places. Loblolly is afflicted with fusiform cankering in a manner similar to slash, and also has the littleleaf disease confronting it. For shortleaf, the littleleaf disease has been exacting such a high toll that the future of the species in rather extensive areas is very doubtful. For each of these trees, there are several other diseases of lesser importance. Included among them are the fairly common heart and butt rots of virgin stands, With shorter rotations, fire control, and reasonably good management practices, the heart rots should fade into relative insignificance in future stands.

In dealing with these diseases, emphasis first has been placed on the indirect method of control through modified silvicultural and management practices. This has seemed the soundest approach, if workable, for the same reason that one would not employ a high-priced specialist using costly antibiotics to do what some self-administered aspirin would do. For brown spot and fusiform rust, the present evidence is that nursery sprays plus modified silvicultural methods may enable us to live with them without too much discomfort. However, it has seemed both wise and necessary to at least skirt the possibilities of increasing resistance to these diseases. The same has been true, but to a much greater degree, for shortleaf in relation to the important littleleaf disease. It will be evident from the following that the work done so far along these lines is in an early stage of development.

Considering the littleleaf disease, apparently healthy shortleaf trees are found at times in the midst of large numbers of killed ones. Selection for resistance, therefore, offers some promise but if this is not successful, breeding for resistance would still be a possibility. Some progress on such a program already has been made through the development of successful cleft-grafting methods of propagating shortleaf pine. Such methods should at least simplyfy the breeding work that may be necessary.

For brown spot of longleaf, the field evidence has been strong that resistant strains could be selected. Early work indicated that a high resin content of the needles, as well as freedom from disease, might also be a criterion of resistance. Since unsprayed nursery seedlings under uniform environmental conditions provide one of the quickest and most certain ways of detecting differences in resistance, work along this line has been started at the Ashe Nursery in Mississippi. Selections made from these beds will be transplanted to a "disease resistance" plot for possible propagation and establishment in disease exposure plots at some later time.

The approach to increased resistance against the fusiform rust canker disease has included geographic seed source and 1-parent progeny plantings in a number of places. Wakeley has already presented strong evidence that different geographic strains of loblolly in the same plantation may vary widely in susceptibility to cankering, and that local strains are likely to be least diseased. Siggers later found that the most heavily cankered strain in the planting mentioned by Wakeley broke dormancy earlier in the spring than did the local strain. This early initiation of growth tended to expose highly susceptible new shoot tissue at the time when the spores that infect pine were at peak production. Further evidence on geographic strains of loblolly in relation to fusiform cankering should be forthcoming from Forest Pathology plots that are in the early stages of yielding results.

As to slash pine, a number of geographic strains have been under test in several localities for as long as 9 years. The oldest of these comparisons involved conventional types of slash pine from South Carolina to Louisiana. In more recent plantings, a native "South Florida" strain and one from Cuba were also included. To date, significant differences in cankering between the various strains have only been shown by the "South Florida" and Cuban slash, the former being strikingly resistant and the latter highly susceptible in comparison with all other strains, in plantings in Mississippi. The "South Florida" strain also has differed greatly in growth characteristics and appearance from all other collections. Within the past year, a slash pine of British Honduras origin has been added to the study. Although exceptional vigor characterized its growth in the seedbed, susceptibility to winter injury (true of the Cuban strain also) may easily prove a limiting factor, regardless of performance against the rust disease.

In conducting the so-called "1-parent progeny" studies, seed have been collected from healthy versus heavily diseased loblolly and slash pine in areas of high rust incidence. Seedlings from both types of parents were established in several plantings that now range from 2 to 5 years in age. The evidence so far has been that the offspring from healthy trees are of little or no greater resistance to cankering than those from diseased trees. Therefore, limiting seed collection to healthy trees is indicated to be of dubious value. This does not mean, however, that the selection of resistant individuals in the field is precluded. In the case of white pine blister rust, for instance, 1-parent progeny comparisons likewise showed little promise in increasing resistance; nevertheless, resistant selections have been made and are now being propagated.

To summarize the pathologist's role in a forest-tree improvement program, I have tried to point out that the phrase "improving the disease situation in future stands" could be easily misinterpreted. This would be true if one visualized the stable type of improvement that is expected for volume production, form, and most other tree qualities. To assume such changes in the

disease situation would be too optimistic, in view of our limited experience and what has happened with increased cultivation of other crop plants. Instead, the pathologist's role probably will be that of struggling constantly to keep disease losses within reasonable limits and to sustain some of the gains that are being made in other tree qualities. To make this fight more effective, I believe we should:

1. Recognize that the indirect silvicultural methods of control will always be a mainstay against many of our diseases, and that the development and application of effective methods are of primary importance wherever the indirect approach can be used. Better application of available methods could improve the health and probably the resistance of our stands today. Such shortcomings in employing indirect control should be increasingly avoided in the future.

2. Accept the belief that increasing the resistance of the tree population is an essential part of every study on important disease problems. This means that geographic seed source and 1-parent progeny comparisons should be made. It also means being on the constant alert for resistant selections, and if such are found, collecting and establishing them in disease resistance plots or recording their location for future use. Eventually, very promising selections should be propagated and widely compared in disease exposure plots. Material also should be supplied foresters, entomologists, and others in the event that additional comparisons seem necessary for other important qualities.

3. Breed for resistance when necessary, particularly in connection with important introduced diseases. If hybrids of definite promise are obtained, they should be widely planted to test disease resistance and other qualities under field conditions. If one parent is of foreign origin, the disease exposure plots should also be established in other countries, particularly in the home of that parent. In fact, such foreign exposure would be advisable for selections as well as hybrids in order to determine and help safeguard against the threat of other foreign diseases.

4. Make every effort to have adequate attention given to the disease phase in all tree-improvement programs. This would include such cooperation as offering to test, or to advise on testing, the disease resistance of all new selections or hybrids that show promise for other qualities.

My concluding remarks are along the lines of the last point mentioned. If the hoped-for progress in tree improvement is to be made, the close cooperation of all interested groups will be a prerequisite. Such cooperation will have to involve the pooling of methods, materials, and even thoughts. There will be less room for independent and guarded effort in this program than in any other type of endeavor in the plant research field.